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Small-Fruit Culture

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A TEXT FOR INSTRUCTION AND REFERENCE WORK
AND A GUIDE FOR FIELD PRACTICE

By

JAMES SHELDON SHOEMAKER

B.S.A., M.S., Ph.D.

Head, Department of Horticulture, Ontario Agricultural College, Guelph, Ontario; formerly Professor of Horticulture, University of Alberta; Associate in Horticulture, Ohio Agricultural Experiment Station, Wooster, Ohio

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PREFACE

The first edition of "Small-Fruit Culture" encountered a pleasing and wide acceptance. Evidently the suggestions from research findings, and the information based on experience, met a definite need. Since first publication, many new and important developments have occurred which should be made available to users of the book; their extent necessitates this revision.

Most of the material prepared for the original edition, and for the reprintings in 1939 and 1945, still remains sound, but the text has been completely and thoroughly reviewed for this new edition. Practical application is still emphasized throughout, whether for the individual gardener or the commercial fruit grower. As in the past, suggestions and criticisms have been sought and utilized.

A large amount of information has been added: the latest research and experimental work, based on over 150 new references, has been included; many varieties which have come to the fore have been described; the new insecticides, such as DDT, have entered into the insect control recommendations; greater emphasis has been placed on the mulching of bramble fruits, currants and gooseberries, and cultivated blueberries; the discussion on the frozen-pack preservation of berries has been modified and enlarged; and such factors as hardiness and the causes of winterkilling of raspberries have been explained.

Increased attention has been given to widespread adaptability of the text by adding material on the youngberry and boysenberry, the vinifera and muscadine grapes, the various types of blueberries, on improved methods of culture, on practices for irrigated sections, and by further description of leading districts. The new edition has been developed over a period of years and with the coöperation of men in the profession at many places across the continent, both in the United States and Canada.

The illustrations have been increased from 52 to 64 in number.

J. S. SHOEMAKER

Guelph, Ontario.

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Introduction

SMALL FRUITS are grown on about 1,750,000 farms in the United States and Canada; the acreage devoted to their culture is nearly 1,000,000 acres, and the annual production is the equivalent of about 3,500,000,000 quarts. The culture of the small fruits is considered in the text in the following order: Grapes; Strawberries; Bramble Fruits—Raspberries, Blackberries, Dewberries, and the Logan, Young, and Boysen types; Currants and Gooseberries; Blueberries; and Cranberries.

The acreage of grapes (about 400,000 acres) in the United States and Canada is about equal to that of all the other small fruits combined. There are about 275,000,000 grapevines, including those of nonbearing age, in vineyards on this continent. These produce nearly 5,000,000,000 pounds of grapes, with a value to the growers of about $50,000,000.

The next in rank is the strawberry, which is grown on about 200,000 acres. In fact, the strawberry exceeds the American-type grape in acreage when it is considered that nearly three fourths of the grapes in America are the European-type species grown in California. About 25 per cent of the total acreage of small fruits in America is strawberries; some 300,000,000 quarts yield annually a return of around $30,000,000.

The combined acreage of bramble fruits is nearly 100,000 acres, the annual production about 100,000,000 quarts, and the value slightly more than $10,000,000. About 18,000 acres of cranberries produce about 60,000,000 quarts with an annual value of $6,000,000. The acreage of blueberries, much of which is "wild," is difficult to estimate but is probably in the neighborhood of 50,000 acres, from which 30,000,000 quarts give a return of slightly over $3,000,000. The acreage of currants and gooseberries amounts to about 2,500 acres.

The culture of small fruits is practiced extensively both in the home garden and commercially. Small fruits, because of the comparatively large number of plants set per given area, the quickness of bearing, and many other factors, provide excellent material for certain types of experi-

ment and research. It is not surprising, therefore, that, for example, the pruning of grapes or raspberries may now be conformed more nearly with "mathematics" than is the case with the tree fruits. However, although highly significant information is available on various phases of small-fruit culture, much of it has not found its way into instruction or field work to the extent which it deserves. One of the purposes of this book is to bring together the scattered information in conveniently usable form.

Stress is placed on fundamentals in the text, thus making possible an interpretation and discussion of the practical application for the varying conditions under which a given small fruit is grown. In a number of cases, it has been advisable to include information, regarding the practices, or methods, prevailing in different localities; for example, the best practices for the strawberry in Florida differ from those in Ohio, Washington, and Ontario.

Each of the small fruits considered in the text constitutes an important commercial industry. In some cases, as with the strawberry, plantings occur in commercial fields and home gardens in most parts of the country; in other cases, as with the cranberry, developments are localized in especially favorable regions and are practically restricted to commercial facilities. An outline of the industries, regions, and districts is given in detail in the separate sections on the various small fruits.

1. Grape Culture

THE GRAPE INDUSTRY, REGIONS, AND DISTRICTS

COMMERCIAL GRAPE growing in America is divided as follows: (1) Regions with European-type varieties, as California and Arizona. (2) Regions with American-type varieties, as (a) the Great Lakes section in New York (including the Finger Lakes and other districts), Pennsylvania, Ohio, and Michigan in the United States, and Ontario in Canada, (b) the west-central section in Iowa, Nebraska, Kansas, Missouri, Illinois, and Arkansas, (c) areas of secondary importance, such as New Jersey, Delaware, Oregon, Washington, and British Columbia. (3) Regions with Rotundifolia or Muscadine grapes, such as the South Atlantic and Gulf States.

Distribution of grapevines in the United States is about as follows:[398]* California, 73.5 per cent; Great Lakes States, 19.0 per cent; west-central states, 4.2 per cent; all other states, 3.3 per cent on a tonnage basis. About 90 per cent of the production is in California.

Regions with European-type grapes

Grape Industry in California. There are more than twice as many grape vines in California than in all other states combined. Raisin varieties, with an annual production of around 1,500,000 tons, make up about 50 per cent or more of the grapes produced. Next in importance are the wine varieties, followed closely by table varieties, each of which produce between 400,000 and 600,000 tons in a year. Dried raisins are estimated at 200,000 to 400,000 tons per year (one ton of raisins is equivalent to about

* Superior numbers designate References, p. 407.

four tons of fresh grapes). The total production of grapes in California fluctuates between 2,000,000 and 3,000,000 tons.

NORTHERN CALIFORNIA. Northern California contains a great interior valley over 400 miles long and 50–75 miles wide, stretching from Redding to Bakersfield, and these grape sections: north part—Sacramento Valley; central part—from Sacramento to Modesto, Central Valley; and south part—San Joaquin Valley. All three parts are protected from the storms and inclemencies of the east by the 10,000-foot rampart of the Sierra Nevada, from the wintry blasts of the north by the Siskiyous, and from the cool summer fogs of the ocean by coast ranges which parallel the ocean shore.

The Intermediate Central Valley is its coolest part, with a moderate rainfall of 12–18 inches and a moderate, effective temperature summation, at Lodi, of about 3,530° F. degree-days* from April 1 to October 31. It owes its relative coolness to the sea breezes which pass through the gap in the coast ranges near the Golden Gate. It is the leading Tokay region. Here also are large areas of vineyards with a heavy production of wine grapes, from which standard table and dessert wines are made.

Proceeding south through the San Joaquin Valley, the average temperature increases, until it reaches, near its center at Fresno, an effective summation of about 4,690 degree-days. The annual rainfall decreases gradually from about 11 inches at Modesto to six inches at Bakersfield. Irrigation is necessary for best results. This is the chief raisin-producing region of California for the large Muscat of Alexandria raisins and the small seedless raisins made from Thompson Seedless. Emperor, an important table grape, is largely confined, commercially, to the San Joaquin Valley, and especially to an area on the east side in Fresno and Tulare Counties. Large quantities of wine grapes are also produced in this valley, especially in the Fresno district.

Proceeding north from the Central Valley, through the Sacramento Valley, the influence of the sea breezes gradually diminishes. The average seasonal sum temperature increases until it reaches about 4,580 degree-days at Chico, or nearly the same as at Fresno. Unlike the San Joaquin, however, the rainfall increases also, until it is about 24 inches at Chico and 37 inches at Redding. Less irrigation is needed than in the San Joaquin

* See Length of Growing Season, p. 34.

Valley. Grape-growing in this region has been less developed than farther south, except in Sutter County and parts of Yuba where Thompson Seedless covers a considerable area. Here, owing to more frequent and earlier autumn rains, special methods are used to hasten drying.

SOUTHERN CALIFORNIA. In Southern California, the main grape-growing region centers in Los Angeles, Riverside, and San Bernardino Counties. Some years ago, Orange County and the west half of Los Angeles County contained more vines than all the rest of California, but the grapes have now been replaced by citrus fruits.

The Colorado Desert region of the Imperial and Coachella valleys is the hottest grape-growing area of California, and produces the earliest grapes.

The chief vineyards in the Coast region are found in Mendocino, Sonoma, Napa, and Santa Clara Counties, but there are also notable areas in all counties abutting San Francisco Bay. The climate here is cooler in summer and warmer in winter than that of the interior valleys and is well suited to the growing of wine grapes.

ARIZONA. This is the only state aside from California in which any large area is suitable for *V. vinifera*. Some of the larger river valleys and mesas below 2,500 feet elevation are well suited for very early Thompson Seedless and Malaga. Commercial grape-growing in this area centers largely in the Salt River, Yuma, and Casa valleys. Of the land comprising the irrigation projects in these valleys, at least 100,000 acres are good grape soil. The chief acreage is in the southwestern part, mostly near Phoenix in Maricopa County. The yearly production is about 2,000 tons.

REGIONS WITH AMERICAN-TYPE GRAPES

GREAT LAKES REGION. This region comprises localized areas in New York, Pennsylvania, Ohio, and Michigan, in the United States, and Ontario in Canada. In good years, the annual production in New York is around 60,000 tons, in Michigan 45,000 tons, in Ohio 25,000 tons, in Pennsylvania 20,000 tons, in Ontario 30,000 tons. The total production in this general area is, therefore, around 180,000 tons a year.

CHAUTAUQUA-ERIE GRAPE BELT. This is a narrow strip 65 miles long and 1 to 5 miles wide, bordered by the southern shore of Lake Erie. The major part of this district is in New York, with its eastern extremity touching Cattaraugus and Erie Counties and extending thence westward across

Chautauqua County. The area in New York is about 40 miles long. The land gradually rises from the lake shore for about 4 miles. Then there is a high hill or escarpment which forms a barrier between the foreland and upland. There is a continuous bench which once was lake beach; at some places there are two such benches. The plantings in New York center largely at Portland, Westfield, Ripley, Silver Creek, Sheridan, Dunkirk, and Fredonia. The western end of the belt reaches across Erie County, Pa., to near Ohio. In Pennsylvania, the North East and Girard districts are the leaders and the Umbrella Kniffin system is much used in training for table grape purposes. In most of this belt the lake moderates the climate, and the slope from the hills insures adequate ground and air drainage, an ideal combination for the grape.

Finger Lakes District.* This district ranks next to the Chautauqua belt in New York. There are three sections which center, respectively, at Keuka, Canandaigua, and Seneca lakes. Some important points are the town of Jerusalem, on Bluff Point, Yates County; across the west branch of Keuka Lake from Bluff Point, at Pulteney, in Steuben County; Naples, in Ontario County; north of Watkins Glen along the east shore of Seneca Lake about Burdett and Hector, in Schuyler County; and at Kendaia near Seneca Lake. The Keuka district in Yates and Steuben Counties is the largest. Hammondsport, in this district, is the chief center of the American-type champagne industry. The Finger Lakes are deep, and it is along the steep slopes abutting the lakes that the grape is cultivated. Varieties that ripen latest are planted on the lower levels, or nearest the lake; early or midseason ones are on the upper portions of the slope. On at least one of these lakes a line of demarcation, which divides the slope into two strips, is plainly evident. That nearest the lake will bring Catawba through to maturity; just above this line Catawba will not ripen, but Concord will. Grapes rarely ripen well on the elevated benches that separate these lakes.

Hudson River Area. It centers in Columbia, Dutchess, Orange, and Ulster Counties. Some points are Highland, Newburgh, Lloyd, and Marlboro. The ameliorating influence of the river, which in places is of some width, coupled with a lower altitude than in the Finger Lakes section.

* The Finger Lakes and Hudson River sections are perhaps not rightfully classified in the Great Lakes region, but it is convenient to discuss them at this point.

insures good maturity in most years. Commercial grape growing is confined rather closely to the river banks.

NIAGARA DISTRICT IN NEW YORK. This area lies to the east of the Niagara River and the southern shore of Lake Ontario, in Erie, Niagara, Orleans, Monroe, and Wayne Counties. The vineyards are located farther from the lake than are those of the Lake Erie basin, but the ridge or escarpment is much higher, and the fruit ripens a week to 10 days later.

MICHIGAN. Michigan ranks third in the acreage of grapes, with about 5 per cent of the vines in the United States. Berrien and Van Buren Counties, with centers at Benton Harbor and Paw Paw, are the leaders. Kalamazoo, Ottawa, and Kent Counties produce grapes in quantity, but their combined acreage is not more than 10 per cent of the Michigan total.

OHIO. At one time, the section along the Ohio River centering at Cincinnati, with 1,500 to 2,000 acres of grapes, was known as the "Rhine of America," but the grape industry there is no longer of major importance; later, this name has been applied to the Keuka Lake district in New York. The work of Nicholas Longworth, Cincinnati, was so outstanding that he was called the "Father of American Grape Culture."

Commercial grape growing in Ohio, with its processing and wine industries, stretches along the southern shore of Lake Erie, chiefly in Ashtabula, Lorain, Lake, Cuyahoga, Erie, Geauga, and Ottawa Counties in the order named. Most vineyards are located on the lake plains and on two or more low sand and gravel ridges paralleling the lake shore and closely adjacent to it, east and west of Cleveland.

About 80 per cent of the Ohio grapes are Concord. East of Cleveland the percentage is higher. In Ottawa and Erie Counties, west of Cleveland, and on adjacent islands, such as Kelley's and Middle Bass, the Catawba variety predominates and ranks second in Ohio with about 10 per cent of the grape acreage. Niagara ranks third (2.5 per cent) and Delaware fourth (2.0 per cent). Sandusky, west of Cleveland, is an important champagne center.

CANADA. About 95 per cent of the Canadian grape acreage is in Ontario. In 1880, this province was credited with only 400 acres of commercial grapes. By 1890, this figure had increased to 2,400 acres, by 1901 to 5,750 acres, and at present to about 8,000 acres. Of this total, 7,500 acres are in Lincoln, Wentworth, and Welland Counties in the Niagara peninsula.

The remaining 500 acres are chiefly in Halton, Essex, and Kent Counties. About 65 per cent of the Ontario grapes is made into wine. As a fruit crop in Ontario, the grape ranks next to the apple in value. Annual production in Ontario is about 65,000,000 pounds (in British Columbia it is about 3,750,000 pounds from about 400 acres). The value of the Ontario crop in a good year is about 2¼ million dollars.

In the Niagara peninsula, the general aspect is north, facing Lake Ontario, with the escarpment in the rear. The most favored locations are back from the lake shore, just below and on the first rise of the escarpment. In some seasons the fruit fails to mature fully in the lake shore vineyards where the cooling effect of the water delays the start of spring growth and tempers the heat of summer. On the other hand, the lake influence sometimes prevents injury from late spring and early fall frosts. Vineyards above the escarpment are especially subject to such injury. Delayed maturity becomes a matter of great concern in cool, wet years when even the most favorably situated vineyards barely mature their crops. Concord matures about October 12 in the Niagara district.

WEST-CENTRAL REGION

The number of vines in Arkansas, Missouri, Illinois, Kansas, Nebraska, and Iowa nearly doubled between 1920 and 1925, i.e., from 8½ to 16 million. The largest expansion occurred in the Ozark area, particularly in northwestern Arkansas and in southwestern Missouri. The annual production is about 10,000 tons in Arkansas, 8,000 in Missouri, 5,000 in Illinois, 3,500 in Iowa, 3,000 in Kansas, and 1,500 in Nebraska. The production in this general area is therefore about 30,000 tons a year.

Arkansas. Grape plantings in Arkansas increased from about 1,700 acres in 1920 to nearly 9,000 acres in 1925, chiefly in Benton and Washington Counties. Prior to 1920, grapes were grown commercially in only two areas in the state, one at Tontitown, which was established by Italian immigrants, and one at Altus, by a group of German-Swiss. Both groups grew varieties other than Concord, which was planted almost exclusively by other growers after 1920, who unfortunately used methods adapted from information gained from growing vinifera grapes in Europe.

Arkansas can be divided into three grape regions: (a) The Ozark plateau north of the Arkansas River and west of the Black River, (b) the Ouachita Mountains, the coastal plain area of the southern part of the

state, and the Crowley Ridge area of eastern Arkansas; (c) the delta and prairie lands of eastern Arkansas from Missouri south to Louisiana, and the Red and Ouachita River valleys in southern and southwestern Arkansas.

MISSOURI. Grape growing began commercially in Missouri about 1850. Between 1860 and 1870 it centered about St. Louis, Hermann, and other river towns. In 1870, Missouri produced more wine than any other state except California, and for some years it was among the leading grape states of the country; but, from 1875 production steadily decreased. Recently, Missouri has experienced a revival of interest in grape-growing, especially in the southwest part. A smaller area occurs in northwest Missouri, near Kansas City, and St. Joseph.

ILLINOIS. In 1870, 40,000 gallons of wine were made in Monroe County, and, in 1874, 55,000 gallons were made in St. Clair County and 600 tons of grapes were sold to the people of Belleville. This was the beginning of the grape industry in southwestern Illinois. This area continues northward and eastward of that around St. Louis, Mo. Grapes began to be planted at Nauvoo, Hancock County, about 1850 and now form the largest acreage in the state. Nauvoo is near the junction of the three states of Illinois, Iowa, and Missouri. The grapes from Nauvoo have largely been ferried across the river and marketed from Montrose, Iowa.

KANSAS. The chief acreage is in the northeastern part; in Doniphan, Wyandotte, Atchison, Johnson, and Miami Counties, where, extending along the Missouri River, it adjoins the areas in northwestern Missouri and southeastern Nebraska. It centers at Wathena. An area also extends westward along the Kansas River from Kansas City to Pottawatomie County, west of Topeka. A smaller area is in south-central Kansas, near Wichita, in Sedgwick County.

NEBRASKA. The chief acreage is in Douglas County near Omaha and on the west side of the Missouri River across from the Council Bluffs district in Iowa. It centers at Florence; other eastern centers are Peru, Brownville, and Lincoln. The Nebraska area extends farther southward along the Missouri River than does the area in Iowa, and, in fact, is a continuation of the northwest area in Missouri and northwest Kansas. Nebraska grapes, and likewise those in western Iowa, ripen at a time when there is comparatively little competition from other heavy producing regions.

IOWA. The chief grape acreage centers at Council Bluffs. The industry

began in 1857, when A. S. Bonham set out a vineyard. As late as 1893, when the Council Bluffs Grape Growers' Association was organized, the vineyard area of this district was only 100 acres. At present it is about 800 acres. A smaller area occurs along the Mississippi River in southeastern Iowa, in Lee County across the river from the area in Hancock County, Ill.; it centers at Montrose, just across from Nauvoo, Ill. Another area occurs near Cedar Rapids and Iowa City in Linn and Johnson Counties. About 100 acres occur near Des Moines. At Council Bluffs, August 25 is the average date of ripening. At Montrose and at Wathena, Kans., grapes ripen 10 days ahead of this date.

AMERICAN-TYPE GRAPE AREAS OF SECONDARY IMPORTANCE

The secondary American-type grape areas occur in a number of states. In Delaware, there is an area of early Concord in Kent County, near Dover and Wyoming. In New Jersey, the yearly production is about 2,600 tons; most vines are in Atlantic, Gloucester, and Camden Counties, and near Vineland in Cumberland County. In Kentucky, there is an area near Louisville in Jefferson County.

In Colorado, commercial production is limited to the warmer and more protected counties. Most grapes grown are of the American type, with vinifera grapes being produced in a small way on the Western Slope. Much of the Colorado demand for American grapes is satisfied by the shipment into the state of Concord grapes a few weeks before the local fruit is ready for market.

Grape production in Washington centers in Yakima, Benton, Franklin, and Walla Walla Counties in eastern Washington and to a smaller extent in King, Mason, and Clark Counties in western Washington. It has had a rather phenomenal increase from 5,700 tons with a farm valuation of $16,000 in 1939, to 18,200 tons with a value of $1,055,600 in 1944. The chief variety grown in eastern Washington is Concord and it is used mainly for juice purposes. Interest in grapes for juice purposes in the Wenatchee district is increasing. In western Washington, Campbell's Early (locally called Island Belle) is the chief variety grown; the area is a little too late for Concord. In Oregon, Clackamas and Washington in the Willamette Valley, and Josephine, in the southern region, are the leading counties, each with 100 acres or somewhat more.

Regions with Rotundifolia or Muscadine Grapes

The muscadine grape region is chiefly in the South Atlantic and Gulf States and includes the entire southeastern coastal plain from the Potomac to Florida, well up into the great coastal plains to southeastern Missouri and the Tennessee River.

In most of the muscadine grape area the temperature rarely goes below 10° F. and practically never to zero. Occasionally vines are found growing beyond these temperature limits, but in such cases they are more or less protected or are not thriving. Though vines have been known to live through periods as low as −10°, they may be damaged at much higher temperatures if the preceding weather has been warm and the change in temperature sudden. Native vines at the northern limits of their range and in the higher altitudes, such as western North Carolina, will stand lower temperatures than will vines in the southern coastal area. The present muscadine varieties are likely to be killed where temperatures as low as 0° F. occur and may be injured at somewhat higher temperatures.

The European- and American-type grapes are known, especially in the South, as bunch grapes. Muscadine grapes are harvested off the stems instead of in clusters. They are often called "berry grapes" because of the tendency of the individual berries of many varieties to shell from the cluster as soon as ripe. Though the berries of most muscadine varieties tend to shell, fruit of some varieties adhere to the cluster as tenaciously as do bunch grapes.

DEVELOPMENT OF GRAPE VARIETIES IN AMERICA*

The number of grape species in America is roughly 25 (see Table 4). Of the natives, *V. labrusca* has been the most productive of superior American varieties.

The Role of *V. vinifera*. The European grape, *V. vinifera*, because of the large acreage in California, is the most important species, commercially, in America. Attempts were made as early as 1616 to grow *V. vinifera* in eastern America. These attempts and many subsequent ones up to the present time have been unsuccessful. Its chief roles in the East have been: (a) Historical, because of its part in early efforts at grape growing; (b) as

* The origin of additional varieties is given under Characteristics, p. 14..

a parent, especially as a pollen parent, in the crossing of species, because most American-type varieties contain *vinifera* "blood"; and (c) as a competitor, through shipment from California, of American-type grapes.

All hermaphroditic American varieties of bunch grapes are thought[152] to have derived their upright stamens by virtue of being not pure species but rather hybrids of these species and *V. vinifera*. The breeding behavior of Concord, Lutie, Clinton, and Champion, once thought to represent pure species, indicate segregation of characters of *V. vinifera*.

The New York Experiment Station has done much breeding work between American and European varieties. For example, Schuyler is a cross of Zinfandel x Ontario, and it may prove to be valuable for red wines and table use. Interlaken Seedless is a cross of Ontario x Thompson Seedless. It is a seedless grape and was developed in collaboration with Dr. A. B. Stout, of the New York Botanical Garden, who worked on the problem of developing hardy seedless grapes at Geneva, N. Y., for more than 25 years.

European blood has been combined with American species in the type known as the French-American hybrids. The *labrusca* species seems to have purposely been avoided in this breeding work, and the emphasis placed on *riparia*, *rupestris*, and *lincecumi*. Seibel 1000 is in bearing in a few commercial plantings on this continent. Seibel 5409 and Seibel 5455 are two other hybrids developed in France by Louis Seibel. Baco 1 is another French-American hybrid. These hybrids were bred and selected chiefly for wine grapes. Seibel 1000 has been reported[153] as surviving a winter temperature of −26° F. and still bearing a full crop the next year. Limited tests indicate good resistance to disease but susceptibility to leaf hopper and berry moth.

Earliest Varieties. Alexander (Cape), one of the first American grapes to be domesticated, appeared about 1800. Isabella appeared in 1818 and Catawba in 1823. Both are *V. labrusca* derivatives and were distributed about the same time, but Catawba assumed the lead, became for a time the most popular American grape, and is still much planted in favorable sections. Norton, a *V. aestivalis* derivative, and Clinton, a *V. riparia* derivative, vied with the labruscas for early prominence, especially for red wine. Ives, which was grown in Cincinnati, Ohio, from seed sown in 1840, also attained early prominence for red wine making.

Concord. Concord originated from seed sown in the fall of 1843, by

E. W. Bull, Concord, Mass., first fruited in 1849, was exhibited before the Massachusetts Horticultural Society in 1852, and was commercially introduced in 1854. The introduction of Concord is a landmark in the history of grape growing. It soon became, and is at present, the leading variety east of the Rocky Mountains.

Quality Grapes. About 1850 increased interest was shown in quality grapes and recorded hybrids of American and European grapes were first brought to attention. Allen's Hybrid was exhibited before the Massachusetts Horticultural Society in 1854; it is honored as the first hybrid (Golden Chasselas x Isabella) in America. However, Ada (Black Hamburg x Isabella) may rightfully deserve the honor, as it was exhibited at Philadelphia two years earlier. Delaware was brought to notice about 1850.

Rogers' Hybrids. In 1851, crosses of American and European grapes were made by E. S. Rogers, Salem, Mass. (Carter was the seed parent, and Black Hamburg and White Chasselas the pollen parents.) Rogers' hybrids with their corresponding number are: 1, Goethe; 3, Massasoit; 4, Wilder; 9, Lindley; 14, Gaertner; 15, Agawam; 19, Merrimac; 28, Requa; 39, Aminia; 41, Essex; 43, Barry; 44, Herbert; and 53, and 22, Salem.

The Period 1870–1890. The following varieties became prominent in this period: Champion, Brighton, Moore Early, Worden, Pocklington, Diamond, Niagara, and Winchell.

The Southwest. T. V. Munson, Denison, Texas, originated a number of varieties especially adapted to the region, e.g., Beacon, Brilliant, Rommel, America, and Carman. He named a number of species of grapes.

California. The Mission grapes, first planted at the Spanish Missions at San Diego and San Gabriel, in 1769 and 1771, were the leading cultivated fruit in California until after 1850. In 1852, vines of Alexandria Muscat and, in 1861, cuttings of Gordo Blanco were imported from Malaga, Spain, by Agostin Haraszthy. At about the same time other importations were made, including Flame Tokay in 1857, which resulted in plantings of grapes especially adapted for raisins and table use. The earliest record of production of cured raisins is 1863 when John Strentzel, Martinez, Calif., and others exhibited Muscat and dried grapes at the California State Fair.

Scuppernong. There is a tradition that the Scuppernong grape (*V. rotundifolia*) was found on Roanoke Island at the time of the landing of Sir Walter Raleigh's colony. The early settlers propagated these white

grapes from seed and destroyed the vines bearing black fruits. The variety now under cultivation originated in Tyrrell County, N. C., in the vicinity of the Scuppernong River, before 1760. (See also Muscadine Varieties.)

CHARACTERISTICS OF GRAPE VARIETIES

Leading European-type Varieties

Alicante Bouschet. Black. Stands third in bearing acreage of wine types in California. Origin—France.

Almeria (Ohanez). Light green to greenish. Spain produces and exports large quantities of Almeria packed in granulated cork. The variety does best when trained on arbors. Artificial pollination is often needed. Origin —Spain.

Cabernet Sauvignon. Black, with a gray bloom. The famous claret wines of the Gironde district of France derive their flavor and character from this variety. It is one of the finest dry-wine varieties in suitable districts in California. Origin — France.

Carignane. Black. A red-wine variety utilized both in sweet- and dry-wine manufacture. Ranks second in bearing acreage of wine grapes in California. Origin—Spain.

Castiza (Molinera, Red Malaga). Red. A table and shipping grape which ripens earlier than Flame Tokay. See also Pollination. Origin —Spain.

Corinthe Noir. Reddish black to black. Berries very small, high in sugar and acidity, mostly seedless. Early. Dried to make the "Zante Currant" raisin of commerce. Grown chiefly in Greece and Australia and only in a minor way in California. Origin—Greece.

Emperor. A deep rose to purplish table grape. Bunch, long and loose; berries large and oblong. A late shipping and storage grape. Ranks second in acreage of table grapes in California. Origin—unknown.

Flame Tokay. A flame-red table grape. Bunch, large and compact; berries, large and oblong. Formerly the Flame Tokay was California's premier table-grape variety. It is now surpassed by both the Thompson Seedless and the Emperor. It owes its importance primarily to its brilliant red color and to its good shipping and keeping qualities. Origin—Algeria.

Grenache. Reddish purple to black. A port-wine type. Origin — Spain.

Johannisberger Riesling. Greenish yellow, speckled with brown russet dots. The Rhine wines of Germany are made principally from this variety. The Franken Riesling endures more warmth than the Johannisberger and is the principal Rhine-wine type grown in California.

Malaga. Yellowish to light amber. Bunch, large and compact. Once California's leading table-grape variety, it has been largely replaced in the market by Thompson Seedless (from girdled vines). It now occupies a relatively minor position, and most of the production is used for distilling material or low-grade wines. Origin—Spain.

Mission. Berries black, small to medium. Valuable as a dessert-white grape. It has always been associated with the making of sweet white wines, such as Angelica. It is low in acidity and too deficient in color to be used alone for red wines. Origin—Spain.

MUSCAT OF ALEXANDRIA. A yellowish green raisin grape. Bunch, long and loose; berries, large and oval. Midseason to medium late. Ranks second in importance in California in raisin production (80 per cent for Thompson Seedless and 15 per cent for Muscat). It is extensively used for muscatel, a dessert wine. Its flavor makes it a favorite home and local-market grape. Origin—North Africa.

PALOMINO. Greenish yellow. Grown for sherry production. Origin—Spain.

PETITE SIRAH (Duriff and Serina). Berries black, small to medium. An important red- dry-wine type. Origin—France.

RIBIER (Alphonse Lavallee). Black. Berries large to very large. Although it is the principal black table grape in California, in total production it ranks only about sixth among all table-grape varieties. Origin—France.

SAUVIGNON BLANC. Whitish yellow. Next to the Semillon, it is the most important variety of the sauternes.

SEMILLON. Golden yellow. The world-famous Sauterne wines of France largely owe their character to this variety. In California, it is best suited to the north coast region. Origin—France.

THOMPSON SEEDLESS (Sultanina). Greenish yellow. Bunch, large, long, compact, and heavily shouldered; berries, small and oval. Early. The leading table and raisin grape. When used as a shipping grape, annual ringing is practiced to increase berry size and improve adherence of berries to cluster. From it are also made large quantities of white dessert wines and much distilling material to furnish alcohol for the fortification of other dessert wines. Constitutes one-third of a vinifera grape acreage in the United States. Origin—Persia (?); first grown in California by Wm. Thompson near Yuba City.

ZINFANDEL. Black. A red-wine type. The leading wine grape in acreage and production in California. Origin—unknown.

LEADING AMERICAN-TYPE VARIETIES

AGAWAM. Red. Vine subject to mildew. Sweet, but foxy. Thick skin, coarse pulp. Stores well. Origin—E. S. Rogers, Salem, Mass.; Carter x Black Hamburg.

BRIGHTON. Red. Thin, easily broken skin. Good quality. Large bunch. Earlier than Concord. Self-unfruitful. Origin—Jacob Moore, Brighton, N. Y.; Diana x Concord.

BUFFALO. Black. About 10 days earlier than Fredonia. Origin—N.Y. Experiment Station; Herbert x Watkins.

CAMPBELL EARLY. Blue-black. Early. None too dependable. A desirable variety only when grown under highly favorable conditions for it, e.g., on light, deep soils. Origin—G. W. Campbell, Delaware, Ohio; Moore Early x a labrusca-vinifera hybrid.

CATAWBA. Red. Ripens late. At its best in only a few favored areas; then, it is an excellent juice or wine grape. It is a leading variety in Ottawa and Erie Counties in northwest Ohio, in the Finger Lakes area, N. Y., and on Pelee Island, Ont. Origin—introduced by John Adlum, District of Columbia. Probably traces back to the banks of the Catawba River, N. C.

CONCORD. Blue-black. The chief variety. The vine is hardy and productive on a wide range of soils and conditions, the yield is large, the fruit ripens evenly, is firm enough to stand reasonable shipment, and is well suited for many purposes. Origin—E. W. Bull, Concord, Mass.

DELAWARE. Red. Small. High quality. Vine rather small. Yield usually lower than Concord. Harvesting per given quantity comparatively slow. Origin—Distributed from Delaware, Ohio, but tracing back at least as far as P. H. Provost, Frenchtown, N. J.

FREDONIA. Blue-black. Ripens about with Moore Early. Berries covered with heavy bloom; quality only fair. Plant vigorous, productive. Origin—N.Y. Experiment Station; Champion x Lucile.

MOORE EARLY. Blue-black. Ripens earlier but usually less productive than Concord. The berries sometimes crack and shell badly and the bunches may be loose. Now being replaced by Fredonia. Origin—B. Moore, Concord, Mass.; seedling of Concord.

NIAGARA. Leading white variety. Vigorous, productive, foxy, large bunch and berry. On suitable, warm, dry soils it acquires a rich golden finish to the berries but otherwise they tend to be green even when fully mature. Origin—C. L. Hoag and B. W. Clark, Lockport, N. Y.; Concord x Cassidy.

ONTARIO. White. Does best on the heavier grape soils. Bunches are a little loose and the fruit does not keep or ship any too well. Good for both dessert and wine purposes, but the wine may not age well. Ripens 3 to 4 days before Moore. Origin—N.Y. Experiment Station; Winchell x Diamond.

PORTLAND. White. A few days earlier than Moore. Quality not as good as Ontario, being somewhat foxy. Better suited than Ontario to sandy soil.

SHERIDAN. Blue-black. Excellent keeping quality. Ripens very late. Origin—N.Y. Experiment Station; Herbert x Worden.

VAN BUREN. Blue-black. Berries smaller than Concord. Good quality for roadside markets. Origin—N.Y. Experiment Station.

WORDEN. Blue-black. Compared with Concord, bunches and berries are larger; it is slightly earlier, not as heavy a bearer, quality better, not as adaptable to varying soils. Crop is improved when it is pollinated by another variety. Berries are apt to split in wet weather. Does not hang on the vines or ship well. Origin—Schuyler Worden, Minette, Oswego County, N. Y.; seedling of Concord.

AMERICAN-TYPE WINE VARIETIES

In most districts, the chief outlet for the grape crop is for wine. In Ohio, for example, about 500,000 gallons of wine are made annually.

Some noteworthy American-type wine varieties are: red wines—Bacchus, Beta, Clevener, Clinton, Concord, Cynthiana, Early Victor, Eumelan, Isabella, Ives, Lomanto, Montefiore, Norton, Schraidt; white wines—Catawba, Delaware, Diamond, Diana, Dutchess, Elvira, Empire State, Etta, Iona, Missouri Riesling, Rommel, Brocton, Ontario. Herbemont and Cunningham (*V. aestivalis*) are popular in the south for white wines. With many varieties which make superior wines the berries are small and the yield per acre low; blending is commonly practiced with the wines from such varieties and that produced in greater bulk from varieties like Concord.

Leading Muscadine Grape Varieties

Scuppernong. White; dark bronze when fully mature. Clusters medium, 3 to 6 berries per bunch; berries $\frac{3}{4}$ inch diameter. The bunches do not ripen uniformly, thus making the fruit troublesome to harvest. Good quality. Makes beautiful arbors in the South. The name is often used to refer to a group as well as to a variety. Origin—see earlier.

Flowers. Black, with many small russet dots. Clusters, medium, 5 to 15 berries. Late. Origin—discovered by "Popping Billy" Flowers in 1819 in Robeson County, N. C.

James. Black. Clusters small, 3 to 6 berries. Berries very large. Late. Origin—discovered about 1866 by B. W. M. James in Pitt County, N. C.

Thomas. Black or dark wine color. Vigorous grower. Early midseason. Cluster small and round. Excellent for unfermented juice and preserves. Origin—discovered between 1850 and 1855 by Drewery Thomas near Marion, S. C.

Mish. Black, with numerous "guinea-egg" specks. Cluster medium size, the berries adhering fairly well to the pedicel. Late, ripens uniformly. It is a fine all-around variety and next to Scuppernong is most highly esteemed as a wine grape. Origin—discovered by Albert Mish between 1840 and 1850 near Washington, N. C.

Eden. Black. Ripens very early and uniformly, though the vines produce distinct first and second crops. Clusters loose, contain 5 to 25 berries each about $\frac{1}{2}$ inch diameter. Well adapted for wine and home uses. Origin—discovered on the premises of a Dr. Guild, near Atlanta, Ga., likely rotundifolia x munsoniana.

DURATION OF VINEYARD, YIELDS, AND COSTS

Before planting a vineyard, the prospective grower should consider, among other factors, the possible life of the planting, the yields which may be obtained, and the costs of development and production. There is a relation between yields per acre and costs and returns, Table 1.

Table 1

Relation between Vineyard Yields per Acre and Costs and Returns, 555 Vineyards in New York, Michigan, Pennsylvania, and Arkansas (American Hortigraphs, April–May, 1931)

Tons per Acre	*Number of Vineyards*	*Growing Cost per Acre*	*Total Cost per Ton*	*Total Hours of Labor per Ton*	*Returns per Hour of Labor*
0.69	57	$ 57	$99	136	$0.07
1.29	136	65	64	80	0.05
1.72	158	72	55	67	0.14
2.26	101	77	48	55	0.26
2.67	62	86	46	51	0.29
3.44	41	100	41	47	0.41

Table 2

COST OF ESTABLISHING 3-YEAR-OLD VINEYARD, PER ACRE. OHIO[7]

MATERIAL COST			
640 vines @ $30.00 per thousand		$19.20	
210 posts @ 32¢ each		67.20	
Wire (3 strands, 13,500 ft., 525 pounds, 11 gauge @ 75¢ per cwt.)		3.95	
Braces for end posts		5.00	
Fertilizer first year	$1.75		
" second year	2.00		
" third year	1.00		
		4.75	
Total material cost			$100.10
LABOR COSTS (MAN LABOR AT 30¢ PER HOUR)			
Plowing, fitting, trenching (first year)		$10.00	
Planting vines		7.00	
Placing posts and wiring		15.00	
Cultivation first year		4.00	
" second year		6.00	
" third year		12.00	
Fertilization first year	$0.75		
" second year	1.10		
" third year	.50		
		2.35	
Trimming second year		1.00	
" third year		2.50	
Tying second and third years		5.00	
Pulling pruned wood off wires and brushing, second and third years		1.50	
			$ 66.35
USE OF LAND (VALUED AT $100 PER ACRE)			
5½% interest and 1½% taxes for three years		$21.00	
Interest on $19.20 for 3 years at 6%		3.46	
Interest on $76.15 for 2 years at 6%		9.14	
Total overhead cost for 3 years			$ 33.60
Total cost for 3 years			$200.05
Credit for grapes harvested			10.00
Total cost			$190.05

Table 3

ANNUAL COST AFTER THIRD YEAR BASED ON 2½ TON YIELD, PER ACRE, OHIO[31]

LABOR COSTS		
Trimming	$3.25	
Pulling brush and burning	3.50	
Tying	3.25	
Repairing posts and wires (mostly labor)	3.00	
Spring disking and plowing	4.00	
Horse hoeing	2.00	
Hand hoeing and applying fertilizer	2.00	
2 cultivations	4.00	
Fall plowing (1 furrow)	2.00	
Picking (2½ tons @ 4¢ per basket)	8.48	
Hauling to barn ($1.00 per ton)	2.50	
Extra labor in harvesting	3.00	
Spraying, two applications at $3.25 per application for labor and machine	6.50	
Drilling cover crop and fertilizer	1.50	
Total annual labor cost		$48.98
MATERIAL COST		
250 lbs. sulfate of ammonia	$ 3.75	
250 lbs. 4-10-6 fertilizer	3.15	
Strings or wires for tying	1.00	
Spray material (2 applications @ $1.75)	3.50	
212 baskets @ 5¢ each	10.60	
2 bu. rye	1.50	
Total material cost per year		$23.50
OVERHEAD COSTS		
Annual depreciation of vineyard based on 20 years of life	$ 5.87	
Annual interest and taxes on land (7% of $100.00)	7.00	
Total overhead cost per year		$12.87
Annual acre cost		$85.35
*Cost per ton (2½ tons per acre)		$34.14

* Farm to market and selling costs are not included, since this varies considerably depending upon local marketing conditions.

Grape plants normally are long lived, and often outlive the men who set them. There are some American-type vineyards more than 75 years old which are still producing profitable crops. In Erie County, Pa.,[187] about 30 per cent of the growers thought their vineyards would last indefinitely, with good care and renewal. About the same number thought the usefulness was limited to 40–50 years. Needless to say, the better the care given a vineyard the longer is its life. There are many old vineyards which no longer are profitable, although some of them still yield well in some years. It would seem better to renew vineyards, particularly on unfavorable soils, after 20–25 years.

With American-type grape plants, set 8 × 10 feet, and with no plants missing, a yield of 15 pounds per vine is at the rate of about four tons per acre. Considering the many factors that affect yield, annual production per acre of one to two tons from mature plants is a poor to fair, and not very profitable yield; 2–3 tons is a fairly good but none too satisfactory crop; 3–4 tons are often the amount required to produce profits; and 4–6 tons are obtained by the better growers of Concord. Yields of Catawba and Delaware are commonly only half that of Concord but the price per ton may be double. Yields of 10–12 tons per acre are not uncommon with European-type grapes in California.

Good yields of muscadine grapes are 25–30 bushels per acre from four-year-old vines, 50–75 bushels from five-year vines, and 100–150 bushels from full-bearing vines.

PROPAGATION

Hardwood Cuttings

Grapes are usually propagated by hardwood cuttings, which may be taken at any time after the plants become dormant and the wood is well ripened or matured. Cuttings are made from the new wood. Canes of medium size are preferable to very large or too spindly ones. The length of grape cutting is usually 8–10 inches or three buds.

In Maryland,[181] one-year-old Concord vines were classified at planting into "weak" (eight inches top growth), "medium" (15 inches), and "strong" (24 inches). Strong and medium vines outyielded weak vines 28 and 22 per cent, respectively (average of nine years). Strong vines gave 4.8 per cent more crop than did medium vines, and 16 per cent heavier average weight of prunings. Five-year records on weight of prunings gave averages of 60.7 ounces, 52.3 ounces, and 44.9 ounces per vine for strong, medium and weak vines, respectively. Strong vines

maintained more regular annual production, and there was no tendency for differences among strong, medium, and weak vines to become less in later years. Perhaps in some vineyards, low yields can be traced to initial weakness in the planting stock, either in weak one-year vines or so-called one-year vines which are developed by cutting back weak vines in the nursery for another year's development.

The vigor of vines the first year was found in Iowa[45] to be directly associated with the vigor of the canes that supplied the cuttings. Cuttings from middle and basal regions of the cane produced the most vigorous vines. The percentage of reserve carbohydrates and nitrogen did not differ appreciably in canes of different vegetative vigor. However, these reserves differed markedly from the base to the tip of a cane, the largest amounts being near the basal end.

Cuttings were taken from high- and low-producing vines in a block of 1,200 Muscat plants where individual records had been kept for five years in California.[46] The strong cuttings reached nearly full bearing in the third year as compared with the fourth year for weaker cuttings.

In preparing cuttings, the cuts are generally made slanting at the lower bud. Another method is to leave a small piece of old wood or a whorl of buds at the butt end; this is the so-called "mallet" type of cutting. As a rule, the position or manner of making the lower cut is not greatly significant.

The cuttings are usually taken in fall or winter after the leaves have dropped, the prunings being used most frequently. They are stored in sand, sawdust, moss, or other material in a cellar or other cool place and kept just moist enough to prevent drying out. In the spring the cuttings are set in a nursery row. Instead of storing cuttings taken in the fall, they may be put in the nursery row and covered with a mulch which will prevent the heaving out of the soil that is due to alternate freezing and thawing. Cuttings may also be buried outdoors.

Cuttings taken in late winter or early spring should be inspected to exclude those damaged by severe weather; they are tied in bundles with the butts turned in one direction and buried several inches deep.

In the spring, after the soil has warmed somewhat, the cuttings are planted 3–12 inches apart in nursery rows or trenches 3–4 feet apart and sufficiently deep so that not more than two buds (usually one) protrude. Some prefer to plant the cuttings slanting. The difficulty in securing a good stand often seems to lie in the moisture relations at the different spots in the field. The soil for the cutting should be well prepared, cultivated frequently, and hoed when necessary. Setting the cuttings directly in the permanent field (even two in each hill) is not a good plan, as a poor

stand usually results. The cuttings are best grown in the nursery row for one year.

MUSCADINE. Propagating muscadine grapes from cuttings is difficult because the wood is very hard, does not callus readily, and does not make

Types of grape cuttings. (*Left*) Lower cut not close to a bud (fairly satisfactory). (*Center*) Lower cut close to a bud (the usual method). (*Right*) "Mallet" type (for special purposes).

roots freely.[190] Better results are secured in northern Florida than in eastern North Carolina under outdoor conditions, the climate being more favorable for the production of roots. In one test, similar lots of cuttings were planted at Willard, N. C., and at Glen Saint Mary, Fla.; Thomas produced 25 per cent of successfully rooted plants at Willard and 75 per

Nursery rows of one-year-old grape cuttings. Note the usual close spacing.

cent at Glen Saint Mary, whereas the figures for Scuppernong, the most difficult variety to root from cuttings, were 2 per cent and 25 per cent, respectively. The results are typical of many other plantings at both locations. In field planting, the best results are obtained by using long cuttings (15–18 inches) of short-jointed, medium-sized, well-ripened wood cut in early winter and stored in a callusing mound until about April 1 and then set in a nursery row in well-prepared ground, with only 1 to 2 buds at the top left above the ground.

Considerable difference exists in the relative rooting qualities of different varieties. Some staminate muscadines root with relative ease. Of the commercial varieties Thomas and Flowers give the best results, James and Eden are intermediate, and Scuppernong roots with greatest difficulty. Memory and Creswell root relatively easily. In the most successful test with Scuppernong at Willard only 4 per cent rooted, whereas with Thomas 48 per cent of the cuttings rooted outdoors.

One means of furthering the rooting of cuttings is to graft small pieces of young muscadine root on the basal end of the cutting and then

treat such grafts as if they were cuttings. In this manner, in a normal year, 86 per cent of Thomas and 30 per cent of Scuppernong cuttings were rooted. Expert propagators can root muscadine grape cuttings with relative ease on a greenhouse bench with bottom heat and regularly maintained proper moisture and soil temperature. Though cuttings do not give as high percentage of plants as do layers, they are easily and quickly made and can be handled in regular nursery rows, and plants grown from cuttings are much better than those from layers.

GRAFTING GRAPES

Bench-grafting Vinifera Grapes[267]

Bench grafting is a method of producing vinifera varieties on roots resistant to phylloxera or nematode. The work is carried on, usually indoors, during late winter and early spring.

The more vigorous rootstocks that have shown wide adaptability and also resistance to attacks of phylloxera include the following:[264] Mourvedre x rupestris, No. 1202; Solonis x Othello, No. 1613; Ganzin, No. 1, and monticola x riparia No. 18815.

Preparing Stock and Scion. Just before grafting, stock and scion materials are removed from storage, are washed clean, and, if at all dry, are soaked for 24 hours in water. Then the stocks are cut to about 11 inches long with the basal cut immediately below the lowest node and the upper cut 1 inch or more above a node. All buds are then completely removed, with a knife or small pruning shears, to prevent the growth of stock suckers in the nursery and later in the vineyard. The disbudded stock cuttings are then graded according to the diameter at the top where the graft is to be made. The grading is usually done by eye into three or four sizes; but if it is done accurately with a slot or notch grader, as many as six or seven sizes may be obtained. Accuracy in grading greatly facilitates and speeds up the work of grafting.

The scions are cut to a single eye with not over $\frac{1}{2}$ inch of internode above and $1\frac{1}{2}$–2 inches of internode below the bud. They are graded according to the diameter at the bottom, into the same series of grades used for the stocks. Economical and successful bench grafting of cuttings requires that stocks and scions be of similar diameter.

The actual grafting is usually done by hand, either the short whip or the long whip graft being used, according to the method of callusing

*Table 4**

SOME CHARACTERISTICS OF AMERICAN SPECIES OF GRAPES[262]

Name and Region of Nativity	*Percentage Cuttings Taking Root*	*Grafting Adaptation*	*Resistance to*				
			Phylloxera, Possible 20	*Cold*	*Dampness*	*Heat*	*Drought*
V. labrusca (northern fox grape): Allegheny Mountains, from New England to South Carolina, Georgia, central Tennessee, southern Indiana	85	BF	5	VG	..	F	F
V. candicans (mustang grape): Oklahoma, Texas, western Louisiana into Mexico	30	F	15	F	F	G	G
V. aestivalis (summer grape): southern New York to Florida; westward to the Mississippi and Missouri Rivers	50	F	14	VG		G	G
V. lincecumi (post-oak or turkey grape): Texas, eastern Louisiana, Oklahoma, Arkansas, and southwestern Missouri	40	F	14	F	..	G	G
V. monticola (sweet mountain grape): Texas	65	FB	18	F	..	G	G
V. berlandieri (little mountain grape): Texas and Mexico	40	F	19	F	..	G	G
V. cordifolia (frost or sour winter grape): Great Lakes to Florida, abundant in Illinois, Tennessee, Missouri, and Arkansas	25	F	18	VG	F	G	G
V. cinerea (sweet winter or ashy grape): Illinois to Texas	25	F	15	F	G	..	..
V. champini (adobe-land grape): Texas	80	FB	12	F	G	G	G
V. doaniana (Texas Panhandle large grape): Panhandle of Texas, New Mexico	60	F	12	F	G	G	..
V. longi (solonis, bush or gulch grape): Texas Panhandle, New Mexico, Arkansas, and Colorado	60	F	14	F	G	G	G
V. rupestris (sand, sugar, or rock grape): from the Rio Grande in Texas northeasterly into Oklahoma, northwestern Arkansas, southern Missouri, Kentucky, and Tennessee; Cumberland Mountains north to Pennsylvania	80	B	19	G		G	G
V. vulpina (*riparia* or riverside grape): from Salt Lake east and from Texas north in all the States as far as 90 miles north of Quebec	85	FB	19	VG	G		
V. bicolor (blue grape): Ontario, Wisconsin, Illinois, Indiana, Ohio, northern Kentucky, western New York, Pennsylvania, New Jersey, Maryland, and northern Virginia	40	F	16	VG	..	G	G
V. rotundifolia (southern Muscadine)	10	..	20	F	F	G	G
V. vinifera (exotic species)	90			F	F	G	G

* Abbreviations. Under grafting: B for bench, F for field. Under resistance, F for fair, G for good, and V for very resistant.

followed. The short whip is made most rapidly and easily. It should be used, however, only where the grafts are hot-room callused, because they are easily broken and must be carefully packed in a supporting medium until they grow together. For sand-callusing, the long whip, tied to secure additional strength, is better.

Short Whip Grafting. Stocks and scions are cut exactly alike except that the cuts are made on the upper end of the stock cutting and on the lower end of the scion. Usually three or more cuts are used to shape both stock and scion. The first cut, at a 45° angle, is seldom straight and true enough for the graft. The second cut removes a thin slice which trues and straightens the first cut. It is made with a single quick, sliding motion of the knife; and, if the surface of the cut is not satisfactory, a completely new one is made, again removing a thin but complete shaving. There must be no paring of the cut, as this makes an irregular or wavy surface that prevents a good fit of the parts.

The tongue is made with a slow sliding motion of the knife. The cut is commenced slightly more than one fourth the distance in from the sharp point of the bevel and continues in a straight plane downward, bisecting the angle of the bevel cut and the grain of the wood, until the tongue is slightly less than half the length of the cut surface. The tongue must be cut, not split, and should be about half as thick as it would be if the knife were allowed to follow the grain of the wood. The knife is slowly withdrawn with an oblique motion to avoid breaking the tongue; and just before it is free of the cut it is carefully bent over to open out the tongue. This technique facilitates the placing together of stock and scion. No cut surface should be visible, and neither stock nor scion should project over the cut surface of the other. It is better that the points do not quite reach the bottom of the cut surface than that they overlap, as the unions will be more complete and the scions less apt to form roots. If the points do overlap, the overlapping portion should be cut off. Tying is unnecessary if the grafts are hot-room callused.

Long Whip Grafting. The cuts correspond to those for the short whip except that the cut surface forms an angle of 15° to 25° with the side of the stock (or scion) instead of 45°. Thus the cut surface for the long whip is $2\frac{1}{2}$–4 times the diameter of the cutting; with the short whip it is about $1\frac{1}{2}$ times the diameter. After scion and stock are put together, the long whip graft is tied with raffia, string, or rubber until they unite by the

growth of their tissues; the less material used the better. Since air is necessary for the formation of healing tissue, clay, wax, tinfoil or other air-excluding material should not be used to cover the union. The tying material is passed several times around the point of the scion to hold the latter down firmly; and then, with 1, 2, or 3 wide spirals, it is carried to the point of the stock, which is fastened firmly with 2 or 3 more turns, the end of the string being passed under the last turn.

Bench-grafting Rootings. If one-year rootings are to be bench-grafted they must first be washed clean. Then they are shortened to a uniform length of about 12 inches and completely disbudded; the roots are cut back to stubs not more than one inch long. One-bud scions are grafted on them by the long whip method. They are usually callused in sand and replanted for a year in the nursery before being set in the vineyard.

When stock cuttings are made, there is always much wood too slender to be bench-grafted. If this is set in the nursery, after one year it is good stock material. Field budding, however, has largely superseded the practice of bench-grafting rootings.

Callusing. When the grafts are made, the stocks and scions are dormant; but, when placed in favorable conditions, they begin growth processes which bring about the rooting of the stock, the sprouting of the scion, and the uniting of one with the other. These favorable conditions seldom exist in the nursery at the time of grafting. If, therefore, the grafts are planted out directly, many will dry or be injured by cold or excess moisture before they can begin active growth. For this reason, newly made grafts are placed where moisture, temperature, and aeration can be controlled until the unions are made.

Long whip grafts are usually tied in bundles of 10 for convenience and economy in handling and callused in moist sand. Raffia treated with bluestone is good for tying. If the temperature of the sand is about 75° F. the unions will callus over and the buds and roots begin to grow in 3–4 weeks. Higher temperatures decrease and lower temperatures increase the time required. Temperatures above 85° cause the formation of profuse, soft callus tissue which may die or be injured by unfavorable conditions during or after planting in the nursery. Below 70°, callus formation is very slow; and below 60° it practically ceases. The grafts should be set in the nursery as soon as the unions are well callused and before the shoots and roots have made excessive growth.

HOT-ROOM CALLUSING. For hot-room callusing the grafts are packed into boxes. These may be of any size, except for the height, which should be 8–10 inches more than the length of the grafts. A convenient size is 16 inches wide, 19½ inches long (inside), and 24 inches high, which holds about 500 grafts. To facilitate packing and unpacking, one side of the box is hinged. Good packing material is a mixture of three parts coarse sawdust and one part "fine chick" charcoal. Since the waterholding capacity of this material is not great, the boxes are lined on the sides and bottom with a one-inch layer of moss. Besides holding water the moss prevents the sawdust-charcoal mixture from sifting out through openings in the boxes. Just before placing the boxes of grafts in the callusing room, they should be warmed to 75° to 80° F. by dipping each box and its contents into warm water to a depth just below the unions. The unions should not be submerged.

After removal from the dipping tank, the box is sprinkled copiously at the top with warm water (80° F). If the packing material settles appreciably, add more. Then, after the box has been set aside to drain, it is ready to go into the callusing (hot) room. This may be any well-ventilated room that can be held at 75° to 80° F. and the moisture within reasonable limits. Light is unnecessary. At 75° F. in the boxes (75° to 80° in the room) the wounds will callus in 3–4 weeks.

HARDENING. When callusing is complete around the wounds, the boxes are transferred to a hardening room which is about 10° F. below that of the callusing room. At this stage the best grafts should show callused unions, indication of root formation, and swelling of the buds. Others will have formed short shoots and short roots; still others will show little or no sign of roots or shoots. At the lower temperature, shoot growth proceeds more slowly, but the unions bridge across with normal conductive tissue which enables the stock and scion to exchange materials. Callus tissue does not do this, and the union is not complete until this conductive tissue forms. After 7–10 days at this lower temperature the grafts are set in the nursery.

PLANTING THE GRAFTS. More care is necessary in planting callused bench grafts than with nursery cuttings. The grafts are set so that the unions are just above the soil. The scions are immediately covered carefully to a depth of 2–3 inches with a wide ridge of soil. Spacing is 3–5 inches in the row.

Bud Grafting Vinifera Grapes[267]

In California the rootstocks are planted in February and March. Before field planting the stock rootings are pruned by cutting off all side rootlets and leaving the basal roots 4–6 inches long. All buds are removed from the stump or original cutting of the rooting to prevent the growth of stock suckers. The top shoot growth of the rooting is pruned back to one or more spurs of two buds each. The rootstock is set so that 2–3 inches of the root stump or portion of the original stock cutting is aboveground. This portion of the cutting furnishes a suitable place to later insert a scion bud. Soil is worked toward the stock vine to keep this portion of the stump protected from drying during summer.

Scion buds are selected from the current year's growing shoots that show maturity by the brown coloring of both the wood and buds.

Bud grafting starts in early August in the cooler coastal sections and about mid-August in the interior valleys in California and can be continued until late September or later in favorable years. A smooth place is selected on the stock slightly above soil level. An oblique downward cut is made on the stock $\frac{3}{4}$–1 inch long and a shorter cut is made into the stock at an acute angle meeting the first cut at its basal end. The chip thus made is removed from the rootstock. By similar cuts on the budstick, making the second oblique cut just below the base of the scion bud, a chip of wood including the bud is obtained. This scion bud chip must be similar in size to the chip removed from the rootstock. The chip bud is fitted tightly into the rootstock with as much of the cambium layers of the bud and the stock coinciding as is possible. The bud chip is held firmly in place by wrapping, e.g., with thin rubber tape $\frac{1}{8}$ inch wide. The budded portion of the stock is then covered with 6–8 inches of moist soil to protect the bud until the next spring.

Grafting American-type Grapes

In New York,[221,225,229,342] Clinton proved the best stock for Catawba, Niagara, and Delaware. The gain in quantity and quality of fruit was profitable. Clinton and St. George were good stocks for Iona, both in yield and quality. Riparia Gloire seemed best for Concord on gravelly loam soils; Clinton gave a large increase of fruit on silt loam. Clinton and Gloire proved best for Campbell, with high yield increases over vines grown on their own roots. Niagara on its own roots averaged, over a

Whip and tongue grafting. (*At the left*) Stock and scion cut for joining. (*Second*) Stock and scion joined. (*Third*) Joined and tied with wax twine. (*Fourth*) The grafted cutting after the callusing process. Note the large pad of callus about the joined parts. (Courtesy, F. E. Gladwin, New York Agr. Exp. Sta.)

13-year period, 1.99 tons per acre as compared with 3.09, 2.91, and 2.66 tons on Clinton, St. George, and Gloire stocks, respectively. Concord on its own roots averaged 2.33 tons, as compared with 3.12, 2.53, and 3.15 on Clinton, St. George, and Gloire. Fruit quality was improved on practically all rootstocks, and usually that stock which resulted in the most fruit and the greatest growth gave the best quality fruit. St. George suckered more than did Clinton or Gloire, and the latter least of the three.

A survey of the work on rootstocks for "bunch" grapes in the South has shown[306] that in the coastal states from Texas to South Carolina, the Dog Ridge, Champanel, and Lukfata stocks (all of *V. champini* parentage) have been effective in increasing the length of vine life and the yield of fruit. In the inland states the main emphasis is on rootstocks that will increase the yields, vigor, and evenness of ripening, especially of the weaker-growing varieties. The best stocks were found to be Constantia (riparia x rupestris), 3309 (riparia x rupestris), 125-1 (cordifolia x riparia),

Cynthiana, Wine King, and Lenoir. These rootstocks were of less benefit at the higher than at the lower elevations.

At Beltsville, Md.,[317] of 11 rootstocks tested with Concord, Delaware, and Ontario scion varieties the rootstocks Constantia, monticola x riparia 18815, and riparia x rupestris 3309 were superior to own-rooted vines for Concord and Delaware. Increase in yield and vine growth was general on these varieties and stocks, though the increase in individual plots was not always significant. Ontario yields were less on most of the rootstocks than on own-rooted vines.

In Arkansas[134] the use of vigorous varieties as rootstocks for Concord, Moore Early, and Campbell Early tended to increase production and size and number of clusters. The most compatible stocks were: For Concord—Cynthiana, Wine King, 41-B, Champion, and 3304; for Moore Early—Cynthiana, 41-B, and Aramon x rupestris No. 1; and for Campbell Early—Cynthiana, Champion, and 3304.

In Missouri[401] dormant budding, or more properly bud grafting, is a more economical method than the whip-and-tongue bench method. It is much faster and gives a higher percentage of takes. The work is done either by hand or by machine, the latter being quicker and more accurate. The chip bud is used in both cases (see also Bud Grafting Vinifera Grapes). In removing the bud from the cane by hand, a cut is made deep into the bud stick beginning about $\frac{1}{4}$ inch below the bud and sloping downward at an angle of about 45°. The second cut is started about $\frac{3}{4}$ inch above the bud, the knife moving on a nearly straight plane behind the bud to the first cut, removing a wedge-shaped piece. The wood in the chip is not removed from the bud. When a machine is used the cutting knives remove a chip in the shape of an isosceles trapezoid (horizontal rather than sloping cut behind the bud, and the upper cut corresponding to the lower 45° but sloping upward instead of coming to a point). When making a bud graft, usually done indoors in late winter, a cutting of the stock and another of the variety desired, of about the same diameter, are selected. All the buds are rubbed off the stock cutting, thus preventing suckering later on. The bud is cut from the variety wood and inserted at a node on the stock cutting. It is tied firmly in place. The cutting is planted so that the bud is slightly above the top of the ground, thus preventing rooting of the bud. When grafting by the stock and scion method, the graft is usually set

below the ground and often the upper wood also takes root, which defeats the purpose of grafting.

By using dormant cuttings, with all buds rubbed off, and bud grafting in the greenhouse, about a year's time is saved over the old method of growing a stock cutting for one year, then digging, cutting off the top, and bench grafting into the stock and replanting in the nursery.

On average Ozark soils, varieties which lack vigor and tend toward light crops of stringy clusters can be improved by grafting on vigorous rootstocks. By grafting Campbell Early on certain rootstocks the average yield over a seven-year period was increased nearly five times over that from cuttings, and the prunings increased nearly six times. Moore Early doubled in fruit and $2\frac{1}{3}$ times in wood. Concord gave $1\frac{1}{2}$ times the fruit and wood. The three best rootstocks were 125-1, 3309, and Constantia (125-1 is a cordifolia x riparia hybrid, and 3309 and Constantia are riparia x rupestris hybrids).

Rootstocks for Grapes in the South

"For decades the history of southern 'bunch' grape growing has been a record of tragedies, and it is only within the last 60 years that much progress has been made. The first attempts were largely efforts to grow the vinifera grapes of Europe, and even though these varieties were under the care of expert European vineyardists, the efforts resulted in total failure. Later efforts were made to grow varieties of American origin. These were mainly labrusca and labrusca-vinifera hybrids from the northern United States. They did somewhat better than the pure vinifera type but they were not successful. Today almost the only grapes successfully grown in the far South are varieties that originated, all or in part, from native southern species, although the use of adapted rootstocks has made it possible to grow a few of the northern labrusca and labrusca hybrids that fail on their own roots."[305]

Layering Grapes

All grapes may be propagated by layering, but it is usually resorted to only with those which root poorly from cuttings, such as *V. rotundifolia*. Another purpose is to refill vacancies in established vineyards. Procedure is different for the two purposes.

Layering is the usual method of propagating muscadine grapes. By this method the greatest number of plants are produced with the least expense. Such plants, however, are often poorly shaped and difficult to handle. Canes may be layered at any season of the year. For midsummer layering, the most favorable time, shoots are bent to the ground and covered with earth, the growing tips being allowed to project above the

soil. Roots form by autumn, and the layers can then be cut from the parent vine, giving one new plant for each shoot layered. If a large branch is layered in fall or spring, it will generally develop shoots from a number of nodes or buds. Roots that develop on these shoot bases can be cut apart during the dormant season, thus securing several plants from each long cane tied down. When such large branches or canes are used they are pegged down in trenches in the spring but are not covered with soil until after shoots start from the various buds. After shoots have started, soil is filled in over the mother cane and about the shoot bases, leaving all shoot tips exposed. The rooted layers are left undisturbed until the next spring, at which time they are taken up and set in new locations.

When muscadine vines are trained on overhead arbors, layers can be made by placing boxes of soil on the arbors and layering the canes into them. In dry periods the earth in these boxes should be kept moist.

New vines of the American-type planted in vacancies in an old vineyard often make poor growth; consequently, layering is preferred. A cane is left long enough, when pruning, to reach beyond the vacancy. A hole 6–8 inches deep is dug at the vacancy. A portion of the cane is fastened down and buried, with the tip protruding; two buds above ground suffice.

Layering is a useful method of filling vacancies in an established vineyard.

The connection with the old vine is maintained until the tip roots. The number of buds on the cane used for the layer is larger than on canes as usually pruned, and so the rest of the vine must be reduced to maintain its vigor and avoid over-production. Another plan is to layer a cane underground to a nearby vacancy, turn the tip upward, and prevent intervening buds from developing.

LOCATION AND SITE

Length of Growing Season

Concord is generally successful in Michigan[352] when the average length of growing season is 170 days, of doubtful success at 157 days, and generally unsuccessful at 145 days. An average mean temperature for May to September, inclusive, of at least 65.5° F., with a growing season longer than 160 days, is essential commercially. A commercial vineyard is successful only with a season sufficiently long to allow the fruit to attain high quality and sweetness nearly every year and then leave a margin of at least 2 weeks for picking. In Ottawa and Erie Counties, Ohio, where the Catawba is a popular variety, the growing season approaches 200 days.

Regions and seasons in which the temperature is comparatively low in the growing months of May, June, and July, and high with much sunshine in the maturing months of August, September, and October produce the best grapes in New York.[246] An average of 55° to 65° F. for the first-named period and of 65° to 75° F. for the second seems ideal. Most varieties in the region fail to produce good grapes if the average rainfall is above six inches for the three growing months and five inches each for the maturing months. It seems better for the crop if the rainfall is as low as four inches for the first-named period and two inches for the second.

Of the various climatic factors at Vineland, N. J.,[83] the amount of sunshine from March to September, inclusive, is subject to the greatest annual variations and is the dominant factor influencing the chemical character of the crop. The content of sugar, acid, and astringent substances in the juices of fully ripened grapes from normally loaded vines is determined very largely by the sunshine in the 214 days between March 1 and September 30.

Vinifera grapes start growth in the spring soon after the daily mean (average of maximum and minimum temperatures for the day) reach 50° F. A winter rest period of two or three months, during which the average daily mean temperature

is below 50°, with some freezing but with no temperatures below 0°, is desirable. Daily mean temperatures of at least 65° are necessary for proper development and ripening of most varieties; and somewhat higher temperatures, 70° to 85°, are needed for some. The time elapsing from blooming to ripening is largely determined for each variety by the effective-heat summation, which, for a given place, is usually calculated by subtracting 50° from the mean temperature for each day and adding together, algebraically, the quantities thus obtained (where whole months are involved, the same result is obtained by multiplying the monthly mean temperature, less 50° F., by the number of days in the month). The result is expressed as degree-days. The earliest varieties require about 1,600 degree-days; the latest, at least 3,500. Beginning the summation of heat at the time of full bloom, Thompson Seedless will be ripe for table use (18° Balling) when the temperature summation above 50° reaches 2,000 degree-days. This variety will be fully ripe for raisins (25° Balling) when the summation reaches 3,000. Similarly, Tokay will be ripe for table use at about 2,300 and Emperor at about 3,200 degree-days.[267a]

Soil and Root System

Grapes are grown successfully on many soil types. Decidedly heavy or extremely light soils should be avoided. Soils which are hard to work, bake readily, and absorb water slowly are undesirable. Light soils are more easily worked, are prepared for planting earlier in the spring, are tilled at less expense, and are better for propagation than are clay soils. Clays, on the other hand, are usually somewhat higher in humus, more retentive of moisture, and naturally more fertile, but often less well-drained than sandy soils. More "heaving" of vines may occur on heavy than on light soils.

Probably the best soil is a well-drained, deep, fertile (high humus content), gravelly or sandy loam, easily tilled, with a subsoil which is not so heavy that it holds the water. A virtue of Concord is its adaptability to a wide range of soils.

It is a rather general belief that grapes on light soils ripen earlier than those on heavier soils. As a rule, this is the case, though more than this one factor is involved. Some sandy soils are cool because of the relatively high water content, and grapes often fail to mature properly and even in favorable years fail to develop as high a sugar content as on the heavier soils. That the harder, heavier clays sometimes may ripen grapes earlier is indicated by studies in Ontario, Canada.[349] Fruit was secured from every area between Burlington and the Niagara River and from the various soil types. Grapes grown on the heavier soils matured earlier than those on the lighter soils especially in a year when all grapes were late in maturing.

Only those on the heavier soils were really fit for marketing when the early frosts came. Also, increased elevation tended to overcome soil influence.

Though there is undoubtedly an influence on time of ripening from soil variability, type of soil may be subordinate to other related factors; e.g., grapes may be immature on weak vines on infertile sand because of insect injury to the leaves (which, also, may be comparatively few in number) and at the same time they may be fully mature on more vigorous vines on more fertile loamy soil in spite of an equal or perhaps heavier infestation. This is possible because of the much larger leaf surface produced per berry by the vines on the more fertile soil.

Water Drainage

Good water drainage is essential in a vineyard. It is probably more significant than soil type. Water standing for any length of time causes damage, even though the grape is somewhat more tolerant in this respect than are some other fruits. The site should slope sufficiently and be free from pockets or basins so that the surface drainage takes care of the surplus water, particularly during late winter or early spring when snow is melting and at other times when tile drainage does not function adequately. Sloping land is not always well drained;[359] especially where the soil is shallow, impervious rock layers or a hardpan below may form basins or "kettle" holes which retain the rainfall from a considerable area and also serve as catch basins for rain falling some distance away.

Before setting a vineyard, poorly drained land should be tiled. Later, if the soil is still wet, surface drainage may be provided, to make the best of the situation, by ridging the rows or by occasional rows of tile that take advantage of the natural depressions. These statements need qualification. There is a sufficient area of well-drained soil in most grape regions to supply any possible demand for the fruit; hence, it seems economically inexpedient to set vines on a soil which must be tiled at large expense. The chief exception is when a small area of poorly drained soil is found in an area otherwise suitable for grapes.

Most vineyards in the Chautauqua belt possess an excellent site; yet some occur where grapes have been set on flat areas between the old beach gravel ridge and the lake shore. This loamy soil is frequently poorly drained and, consequently, is unsuited for grape production in such spots.

Heavy soils with an excess of water become lumpy when plowed, and

the texture may remain poor for much of the season. Cool soils usually delay ripening; also, when the soil is so wet that it cannot be worked until late, the effective growing period is shortened. Fertilizer or good cultural care fail to give desired results in fields where drainage is the limiting factor until the drainage is improved.

A water level within 6–8 inches of the surface during winter causes root killing below that level because of lack of air. The result is equivalent to cutting off the roots at the 6–8 inch depth. Severe reduction of the root system dwarfs growth of the parts aboveground. "There are two similar regions in Michigan where Concord grapes have been grown successfully where the water table is high—in Monroe and Ottawa Counties. The vines are set on an open soil in flats near the edge of the water (along the Grand and Raisin Rivers). The water table is comparatively constant instead of fluctuating widely as it does in most poorly drained soils. Vines or other fruits set on poorly drained soils usually suffer most from drought when the water table falls faster than the roots can follow the receding moisture."*

Exposure, Winter Injury, and Frost Protection

Injury from late spring frosts is greatly avoided by choosing a site with enough slope or elevation for good air drainage and free from pockets. Some vineyards have been planted where yield over a five-year period has been reduced 50 per cent or more by frost injury; whereas other vineyards within a few miles have lost less than 1 per cent from that cause. Low situations or others that prevent a free circulation of air are not conducive to good control of diseases.

Steep slopes are likely to wash and cannot be worked so well as land more nearly level. The practice sometimes has been, after the land is cleared, to grow general farm crops until the hillsides become so badly eroded that field crops can no longer be produced satisfactorily; then grapes are set. These lands are submarginal because they have lost their most fertile surface soil. Fertilizer washes down the slopes, cover crops scarcely sprout, and the soil can be restored (if at all) only at great expense. Terracing and soil building are too expensive when the fruit from an overcapitalized vineyard must be sold in competition with fruit grown on

* Correspondence with N. L. Partridge, Michigan Agricultural Experiment Station.

naturally fertile soil. When grapes are planted on hillsides, the rows should follow the contour of the land.

The grape is one of the last fruits to bloom; often, strawberries are being picked before nearby grapes bloom. Because of late bloom it might be expected that the grape would be less subject to damage from frosts than other fruits, but this is not necessarily the case. The habit of growth of the grape must be considered in relation to frost hazard. The new shoots start early in the spring, for several weeks are very succulent and tender, and are often damaged by frost before the blossoms on them open.

Large bodies of water modify the temperature surrounding them. Spring frosts do not occur so late as at points farther in the interior, and the expanse of melting ice retards the starting of the buds until the season is so far advanced that they ordinarily escape injury from late frosts or freezes. The water of Lake Erie one foot below the surface during May is only 7° F. above freezing.[228] Usually in mid- to late July it gradually rises to the atmospheric temperature, and from August until late fall the temperature of the lake water is several degrees higher than that of the air. In September it is 3°–4° warmer, and in late October it is often 6° warmer. These ameliorating influences of course vary from year to year. If the winter has been mild, little ice forms and the retardation of buds is at a minimum; but, if ice forms over a considerable area of Lake Erie, very rarely are the buds injured from late frosts or freezes. Growth normally starts in the spring in the region immediately bordering the lake shore considerably later than a few miles inland and, in the fall, the fruit ripens later closer to the lake. The warmer air, more or less confined to the lake plain because of the ridge paralleling the lake to the south, wards off early fall frosts and thus gives to the region several more growing days than in places several degrees farther south. As the ridge approaches the lake shore, or the area confined between lake and ridge becomes narrower, frosts and freezes in the fall are delayed; e.g., ice may form at one place, but 15 miles to the west and at the same elevation freezing temperature may not occur until several days later. The presence of large bodies of water, such as Lake Erie, assures an optimum humidity, and at the same time there are very few days during the growing season that the air is not in some motion. With excessive humidity lacking and air currents almost continuous, this region is unfavorable for the infection and spread of diseases.

Light frosts in the fall injure the foliage and heavy freezes injure both

fruit and foliage. Poor air drainage occurs in low spots in hilly sections. The direction of the slope is important, but the need for southern or eastern slopes is often overemphasized. Sometimes, however, particularly in sections which are not the best for grapes and where late varieties are grown, a southern or eastern exposure is better than a northern or western one because of greater opportunity for ripening of the fruit. Mostly, delaying growth in the spring by a northern exposure is the chief factor.

About half the fruit buds in Concord vineyards at Fredonia, N. Y., were killed during the winter of 1909–1910. The injury was traced[218] to a lack of maturity of the tissues owing to a sudden termination of the maturing period on October 12, 1909, by unseasonably low temperature. Records for eight years indicated that the sugar content of the grape in any year is closely correlated with cane and bud maturity of the year. The lightest crops followed the years of lowest sugar content.

The wood of the canes of American-type grapes is less susceptible to injury than the buds. In New Jersey[104] few varieties survive minimum winter temperatures of 4° F. with 100 per cent of the buds uninjured. But, when there are a large number of buds injured, some buds which would otherwise remain dormant may be forced into growth. Also, the killing of a few buds may have somewhat the same effect as thinning and result in larger clusters from the buds that are left. There may be injury when none is suspected, and relatively unproductive shoots from secondary buds may give the vine an appearance of normal growth.

When the first shoots are killed the secondary growths may produce a partial crop. In West Virginia,[10] on April 21, the shoots were 10 inches long, with the blossom clusters showing plainly. The temperature fell to 23° F. during the night of the 21st and on the night of the 23rd. The first shoots were killed in all varieties. About mid-May new shoots began to appear. A fairly consistent type of recovery was found, limited mainly to buds which most likely would not have produced shoots in a normal year. The crop from the second growth was light, but it was distinct from the complete failures in many other fruits.

In Arkansas,[134] cutting the canes back to 3–6 nodes after frost injury resulted in the most satisfactory renewal wood for the next year. With shoots six inches or more long at the time of injury, the resultant current crop did not pay for removing the shoots.

A possible means of preventing damage from freezes or frosts in the

spring is the use of heaters. In practice, however, the inconvenience and cost of heating and the uncertainty of the occurrence of damaging temperatures have been such that it is seldom profitable with American-type grapes.

Vines of European-type grapes may be adequately protected from winter injury by laying them down and covering with straw held in place by a little soil, according to tests in Illinois.[113] Survival of the winter, however, does not of itself adapt European varieties to the eastern part of the country. Subsequently, the behavior of this species is much different from that in California. In very cold regions the standard varieties of the east need covering in order to survive the winter.

Erosion

When erosion removes soil, the roots may be injured in cultivation or by other causes. This reduces the vigor of the vine and its ability to produce superior fruit. Rapid erosion is a decided disadvantage. With slight erosion, especially on rich soil, the vines may be able to renew their roots in the lower parts of the soil rapidly enough to offset the loss of the upper roots.

Erosion in vineyards is of two common types: (a) due to water, through gullying or sheet erosion, and (b) due to wind. Gullying usually occurs on steep hills and is the more rapid means by which vines are destroyed. Sheet erosion occurs without the formation of noticeable gullies and acts more slowly. But, it is really more dangerous than gullying,[759] because the effect is seldom noticed until conditions become critical over a wide area. Erosion by water may be reduced in part by these practical means: (a) planting so that the rows are placed across the direction of the slope, thus permitting level cultivation; (b) letting grass grow in the rows, which holds the soil and in course of time leads to the formation of terraces corresponding to the different rows (permitting sod to develop is making the best of an undesirable condition); (c) increasing the capacity of the soil to absorb water rapidly by applying manure or by plowing in cover crops to add humus; and (d) protecting the ground during the dormant period with a cover crop. Erosion by wind occurs mainly on light soils and mostly on bare ground, and is reduced by cover crops.

When erosion occurs, good vigor of vines encourages the development of new roots to replace those that are damaged. Adverse conditions should

be avoided through the selection of a good site instead of attempting remedial means.

PLANTING

Preparation of Soil

A well-pulverized soil is conducive to a good stand of plants, for they not only survive planting but become established quickly. Treatment of the soil should begin at least the year previous to planting, preferably earlier. It is important to build up humus in soil which is to be planted to grapes. Plowing in the fall and working the soil down early in the spring, to make it friable, smooth, and ready for early planting are advised. If plowing is not done in the fall it should be done as soon as the soil is dry enough in the spring. Thorough preparation of the soil for plants that are set successfully in the fall, or at times other than spring, is also necessary for best results.

Preparatory to planting, a good plan is to plow the field deeply, either with a two-horse plow or with a tractor plow, into "lands" eight, nine, or 10 feet wide, according to the spacing desired for the rows. Then with a subsoil plow, each dead furrow may be gone through twice, thus loosening the soil to a much greater depth. By going through the dead furrow again with the two-horse plow much of the loose soil may be thrown out. The probability of a wider and more rapid extension of the root system is thus enhanced.

Time of Planting

Grape plants are set successfully in either fall or spring, the best time being determined to some extent by geographical location. Early spring planting is usually best, just as soon as the soil can be well prepared. An early start, as compared with a late start, for the plants in the spring may mean the difference of a year in establishing the vines on the trellis. Grape plants with buds that have started can be set successfully in late spring but require more special care in setting them than plants that are dormant or nearly so.

For physical reasons in northern regions, October and May plantings cannot be recommended. In October the vines are usually in almost full foliage. To prevent serious drying out, leaf removal is required, and this extra labor adds to the cost of the vines. In early May the buds are swollen

or actually burst, and so are easily rubbed off and, even though this does not cause death of the vines, they are given a setback. In most years also there is some difficulty in obtaining, at one and the same time, suitable weather and soil conditions for a December planting. For practical purposes, therefore, November and April are best, according to work of W. H. Upshall of the Vineland Station, the grower making his decision on the basis of convenience.

Fall planting is sometimes done with success, but when plants are set at this time damage from heaving and winterkilling may be encountered. If set in the fall, especially late fall, the plants may be covered with a mulch to prevent heaving during the winter; this mulch should be removed in the spring before the buds swell. In Arkansas and in states towards the southern limit of grape culture the advantage is probably in favor of fall planting.

Choice of Plants

Vigorous grape plants of one year's growth generally are the most suitable and economical to plant. Two-year plants are suitable under a more restricted range of conditions. However, if one-year plants are not well grown, two-year ones may be preferable as they may have a larger root system and may produce more vigorous growth in the first year. As a rule, weak plants are unprofitable and should be discarded. It is desirable that the plants to be set possess well developed root systems and a good but not excessive top growth.

Quite often the two-year plants are the culls of the preceding year. Observations in New York have shown that, as a rule, if growing conditions are favorable, good cuttings make No. 1 and Extra vines the first year in the nursery. The weaker cuttings furnish the No. 2's and culls. Hence, desirable two-year plants are not grown from the No. 2's and culls of the previous year but are those that graded No. 1 or Extra and were transplanted to the nursery for another year. Most commercial vineyards are set with one-year vines; the amateur inclines to older plants.

When cuttings are used the variety becomes established on its own roots. Bench grafts are made so that the scion is of one kind and the root another. Grafts grown a year in the nursery are suitable for planting.

Mature plants can be moved when dormant, providing they are dug carefully and are pruned severely, but the period of recovery of both root

and top is comparatively long and the results generally are less satisfactory than if a nursery plant is set out. It is seldom advisable to move a vine that is more than four years old.

Direction of Rows

The slope of the land is probably the chief factor to consider in determining the direction of the rows. On steep hillsides or gradually sloping land, the rows should run at right angles to the slope or follow the contour of the land. Rows laid out in this way make cultural operations easier and help to check erosion. Vineyards must be cultivated some each year, and erosion of the topsoil is a rather serious matter in some grape sections.

If the land is level, probably the best exposure to the sun results from running the rows north and south when the vines are farther apart in the row than the rows are from each other, and east and west when the distance between the vines is less than that between the rows. If strong winds prevail, there is less damage to the vines if the rows run in the direction of the winds so that the wind blows down between the rows rather than across them.

Planting Distance

Some factors involved here are: provision for ample space for the best and most economical disposal of the aerial parts of the vine; reservation of sufficient soil area so that the roots may have ample opportunity to forage; convenience in tillage, spraying, and other operations; soil fertility; varietal habits; the site itself, whether sloping steeply or more nearly level; the use of alleys; the size and shape of the planting; and direct influence on yield.

Spacing 8–9 feet in rows 10 feet apart is a good general guide. Changes in this spacing are advisable according to various conditions. Usually on soil fertile enough to be better than marginal, when vines are set 10 feet apart in the row the yield is as high as at eight feet. Vines set on the lighter, sandy soils require more feeding space than do the same varieties on clay. The greater the space between vines, the larger they grow; this compensates for the greater distance. The fewer the vines per acre, the less it costs to establish and operate the vineyard, and pruning, tying, spraying, and other operations are much easier.

Too close planting is a common error. In commercial vineyards a space of 8–10 feet between rows is usually needed so that tractors, teams, sprayers, etc., may pass between the rows without injury to the vines. To operate some implements in a vineyard, a space of 10 feet between rows is necessary.

Varieties differ in inherent vigor. Delaware, for example, makes less growth than Concord and usually is planted closer in the row.

Sometimes, most of the rows are spaced 8 feet and every fourth row is 10 feet apart. This provides room for a driveway. When the vineyard is to cover more than 3 acres, it is best to provide alleys or driveways for each three-acre area, running parallel and crosswise to the rows. These alleys facilitate vineyard operations, especially cultivation, spraying, and harvesting. The alleys should be wide enough to permit of easy turning with a tractor.

In fertile soils and hot climates each European-type vine requires about 100 square feet or more. For cooler climates and less fertile soils and small-growing vines, about 80 square feet are sufficient. For square planting and vase-formed vines, 9 × 9 feet or 10 × 10 feet are appropriate, with convenient avenues of 18–20 feet. For avenue planting or trellised vineyards, 8 × 10 feet or 8 × 12 feet for vase-formed table grapes and 6 × 12 or 7 × 14 feet for raisin or trellis types are usual.[47]

When grapes are set 8 × 10 feet, 544 plants are required for an acre.*

Muscadine vines grown on the overhead arbor or horizontal trellis have usually been planted 20 × 20 feet apart. Where they are grown without intercropping it is advantageous to set the vines about 10 × 10 feet apart and then thin them out as they begin to crowd. In this manner, much heavier yields per acre can be obtained from the first three or four harvests. Another method of handling is to set the vines 20 × 20 feet and use the interspace for other crops.

On a vertical trellis, Scuppernong and similar strong-growing sorts should be in rows not less than 10 feet apart. Vines may be set 10 feet apart in the row and thinned to 16 feet. With Thomas, which is inter-

* The number of plants required to set an acre is obtained by multiplying the distance between rows by the distance apart in the row, in feet, and dividing the product into 43,560, the number of square feet in an acre. For a smaller area, the same procedure is followed except that, instead of dividing into 43,560, divide into the number of square feet contained in the area to be planted.

mediate in vigor between Scuppernong and Flowers, it is best to set the vines 15 × 15 feet for overhead training and 15 feet apart in rows 10 feet apart for vertical training.

Pollination

Most grape varieties are self-fruitful, but some are self-unfruitful. All self-unfruitful varieties, e.g., Lindley, Herbert, and Brighton are improved by interplanting good pollinators such as Concord or almost any self-fruitful variety. Brighton apparently is easily cross-pollinated, as it invariably sets good crops of large, well-filled bunches. Lindley and Herbert are less easily handled as, even where ample provision has been made for cross-pollination, the bunches are often straggly and the yield light. Loose bunches are characteristic of self-unfruitful grapes when they are left to open-pollination. The straggly bunches which often occur on Campbell Early largely involve factors of pruning and site.

Self-fruitful grapes have upright stamens. Pollen from varieties with reflexed or recurved stamens is worthless for pollination, as in Amber

Lindley. (*Left*) Hand-pollinated; 75 flowers; weight of fruit 85 grams. (*Right*) Open-pollinated; 80 flowers; weight of fruit 23 grams. (Courtesy, Olav Einset, New York Agr. Exp. Sta.)

Queen, Banner, Brighton, Eclipse, Gaertner, Herbert, King Philip, Lindley, Massasoit, Merrimac, Moyer, Pontiac, Salem, Wilder, and Wyoming.

The first commercial plantings of Almeria (Ohanez) in California in the late 1870's were failures because of low and irregular yields. Changes in the pruning system, and use of fertilizer, did not materially increase yields. In Spain provisions are made for artificial pollination. This is one reason why the variety is grown there on overhead arbors, about seven feet high, and the trunk is branched horizontally in all directions on the top, to give great spread to the arms. The blossom clusters thus hang free and are easily manipulated. At one time a wild male vinifera called "Flor" that was allowed to grow along fence rows and waste places furnished much of the pollen. After the introduction of rootstock varieties from France to combat phylloxera, many riparia and rupestris hybrids were allowed to grow without grafting, and also furnished pollen. They were called "Parras Locas" or "crazy vines." Of late years the Spanish growers have widely used various fruiting varieties, such as Molinera (Red Malaga), which overlap Almeria in bloom and are also a source of salable fruit. The term "Castiga" is used collectively to denote the whole group of vinifera varieties that are used for pollination and produce marketable fruit.

In Spain, blossoming clusters are cut from any variety available and tied or inserted as a small bouquet at the end of a bamboo cane or stick about three feet long. The Almeria clusters in blossom are then rubbed or brushed with this bouquet. When possible, the hand is placed against the cluster during pollination to prevent breakage and when withdrawn is gently passed over the cluster. Such pollination is carried on during a 15-day period, every vine being gone over every other day.

The flower of Almeria has completely reflexed stamens and the pollen does not germinate *in vitro*.[313] Though some pollen grains are able to bring about fertilization, this is such a rarity that self-pollination, either naturally or artificially, does not materially affect the fruit set. The early commercial failure of this variety to set regularly in California can be attributed to insufficient cross-pollination. Both wind and insects are agencies in cross-pollination, the former probably being the more important.

Muscat grapes are very subject to coulure (shelling) and to millerandage (production of small, seedless berries). Less severe pruning than is the usual custom in California increases the viability of pollen, the set of normal berries, and the percentage of normal berries to a bunch. Both the male and female parts are improved by the lighter pruning because of an earlier development of the foliage and an increase in its area.[520] A decrease in the number of leaves per vine is accompanied by a smaller capacity for production, a decrease in weight of cluster, a decrease in percent of normal berries to a cluster, and a decrease in the weight of berry. There is, moreover, a great decrease in the tendency to coulure and to millerandage, especially in Muscat.[521] The responses are correlated with increased carbohydrate supply which is associated with greater leaf surface.

It has often been assumed that the smaller-sized berries on clusters of normal seeded varieties, especially those of spherical shape and frequently referred to as "shot berries," were parthenocarpic and result from vegetative development. Thus Stout[437] mentions that three types of berries most likely make up the cluster of *seeded* varieties: (a) seeded berries, (b) stenospermocarpic, and (c) parthenocarpic. Lack of pollination has often been cited as a cause of the development of the stenospermocarpic (or "seedless") fruits. Thus the poor set of seeded berries and the large number of small "seedless" berries often reported in vineyards of the Muscat of Alexandria has repeatedly been attributed by various workers to the lack of pollination. Actually, these fruits are not entirely seedless,[311] at least one rudimentary seed being present. They may be very small in size, yet there is no doubt that even this small amount of seed development is chiefly responsible for the enlargement of the berry and the retention of the fruit on the vine to maturity. Pollination, therefore, is necessary to obtain "seedless" berries (in seeded varieties) as well as seeded ones.

Shelling of berries from the clusters soon after bloom and the development of shot berries are common symptoms of little-leaf disease, which in most varieties is also associated with small, chlorotic, and deformed leaves. Zinc is useful in some cases to promote recovery from little-leaf and to overcome shelling.[93,249,444] It is applied by treating the wounds immediately after pruning with a solution of two pounds zinc sulfate in one gallon of water, or as a foliage spray, 10–14 days before bloom, using a suspension of 25 pounds zinc oxide in 100 gallons of water.

Heeling-in

This is a valuable practice for holding plants for a reasonable length of time, but it is at best only a makeshift for planting directly. The plants are closely arranged in a single row in such manner that the roots of each plant are in direct contact with the soil.

Setting Grape Plants

The soil should be well prepared, as for most crops, before setting the plants. Unless the plants are set in straight rows, difficulty is encountered in aligning the trellis and in subsequent cultural operations.

For fields of one or more acres, a good plan is to place stakes 5–6 feet high in the spots where the end vines of both outside rows are to be located. Then, by sighting on these, intermediate stakes, two or more in number, are placed in the same alignment. With these stakes as guides, a man, starting from the stake in one outside row, draws a heavy log chain across the dead furrows till the other outside stake is reached. The marks left by the chain where it intersects the dead furrows locate the exact spot where the vines should be set. Before starting back across the field, the man with the chain measures down the outside row, where he now is, eight feet from the intersection of chain mark and dead furrow, or at any desired distance, and again places the stake. A helper on the far side does likewise, and intermediate stakes are then lined up by sighting. The chain is then drawn back to the opposite side, keeping in line with the stakes. This procedure is followed until the entire field is check marked.

At the spots where the chain marks intersect each dead furrow a hole is dug large enough to accommodate the roots and provide the same depth as the plants stood in the nursery. Injured, broken, or straggling roots are cut back before setting. In filling the hole with soil, allowing fine soil to sift down around the roots helps in their establishment. After the roots are covered the soil should be tamped with the feet. The hole is then filled to ground level and loose soil placed on top, or the final filling is done by plowing furrows.

Either before or after setting, the plant should be pruned. All but one cane should be removed, and this one should be shortened to two buds. One advantage of waiting until after the plants are set and growth is starting before pruning is that if some of the buds have been damaged in handling this can be taken into account. This pruning makes the vine less

likely to dry out before rooting and forces the growth from the few remaining buds, thus producing more vigorous shoots. Besides the single two-bud cane a one-bud stub may be left as a convenient place to tie the grape twine when the vines are to be trained to the trellis in the year of planting. Tying the twine to the stub rather than the cane avoids girdling as the cane increases in size.

FRUITING HABIT AND FRUIT-BUD FORMATION

Constitution of Buds

On a young shoot, two buds develop in the axil of each leaf, but as they are enclosed in a common protective scale they look like one bud. Upon growth extension, they separate and one gives rise to a short lateral shoot which generally falls with the leaves in autumn. The other bud in the meantime has developed two accessory buds, one on each side, and the three (or more to include progressively less developed buds) thus formed, as well as the one giving rise to the short lateral shoot, are enclosed in common scales so that they appear as one large bud, which is really a group of buds or a compound bud or "eye." The side buds seldom develop further and the central bud constitutes the main unit. The compound bud remains dormant over winter; it is a more complicated structure than the mixed bud which contains both flowers and leaves.

"The inflorescence of the grape is a racemose panicle. The main axis bears lateral axes of the first order, and these, in turn, bear lateral axes of the second and third orders. The lateral axes arising near the base of the rachis are longer and more profusely branched than those arising from the more distal regions. The degree of branching gradually decreases toward the apex, so that the distal part of the cluster usually consists of simple axes. The cluster of fruit borne by each axis is referred to as a secondary, tertiary, or quartenary cluster, according to the order of the axis from which it has developed. This of course is not true where the pedicel is attached directly to the rachis, inasmuch as a single fruit can hardly be considered a cluster."[445]

Fruit-bud Formation

In Michigan,[361] fruit-bud initiation occurs in midsummer. The primordium remains a mass of heavily nucleated cells till spring, when the cluster develops after growth starts. In Iowa,[445] differentiation begins early

in June and continues in the newly forming buds throughout the growing season. Cluster primordia are initiated during early June in California. They appear as blunt, rather broad outgrowths of the growing point of the bud. The leaf primordium, however, appears as a pointed outgrowth from the growing point and is readily distinguished from the cluster primordium. The primordial clusters in the basal and apical buds of the canes do not become so large as those in the buds in the middle of the canes. In Australia,[29] with Sultana, differentiation occurs first in the basal bud, eight days later in the sixth bud, 16 days later in the eighth bud, and 29 days later in the sixteenth bud.

The Fruiting Cluster

The fruiting cluster of the grape[361] is morphologically a modified tendril. The development of a tendril into a blossom cluster depends upon the internal condition of the plant. Clusters are found with "shoulders" or a large secondary cluster on one side, without a shoulder, with a tendril instead of a shoulder, and tendrils are often found with a few blossom buds on their sides. The usual position of blossom clusters is opposite the leaves at nodes 3, 4, 5, and 6 of the spring shoots of Concord.

Influence of Nutrition on the Cluster

A large primordium in the dormant bud depends upon the presence of a good supply of "food" at the node. The number of blossoms that develop in a cluster is largely dependent[361] upon growing conditions in the spring, which determine how the stored food is to be utilized and also the amount of carbohydrates that may be produced in the young leaves. The fruiting of a cane is related also to the external characteristics of the dormant cane. This relationship extends to the weight of the fruit clusters as well as to the number of bunches developed per shoot, and is evidence that the large clusters develop from over-wintering primordia, for the external characteristics of the cane are merely an expression of the manner in which shoot growth took place the preceding year. The association of large bunches with the largest number of bunches per shoot is not absolute, though the shoots with the largest number of bunches usually produce bunches of good size. This indicates that a cane tends to maintain the favorable or unfavorable nutritional conditions which characterized the shoot the preceding year. If growth conditions at that time were

favorable for primordia development, there was also a larger store of carbohydrates laid down near these nodes, which are more likely to produce well. This food material is not only available to supply the primordia which are developing and to aid in cane "maturity" but also gives the young shoot a good supply early in the spring to promote vigorous growth.

There is a positive correlation between the vigor or length of shoots and the number of blossom buds differentiated in the cluster. Unless conditions in spring permit full development of the primordium, the blossom clusters will not reach full size. In a group of 26 canes whose length ranged from 17–117 cm. on June 19, the number of blossom buds differentiated in the largest cluster (the basal one on each cane) on the seven shoots ranging from 17–29 cm. in length averaged 75, on the four shoots from 40–59 cm. it was 87, on the 10 shoots from 63–81 cm. it was 137, and on the five shoots from 93–117 cm. it was 130. Bloom was over and the grapes were set within a month from this date.

The number of bunches is probably more closely associated with the characteristics of the cane than with those of the shoot, and the size of the blossom cluster is more closely tied up with the characteristics of the shoot growth than that of the cane. Number of bunches and size of bunch both affect total yield. Which is the more important in determining the crop may depend upon the normal size of the bunches of the variety. In those in which the bunches are small, their number is probably of greater significance; and in those varieties in which the bunches can attain large size, size of bunch is probably the more important.

Though growth in one year predisposes a given cane to high, low, or medium fruitfulness in the next year, there is also a distinct influence exerted by conditions in the spring, quite apart from those of the preceding year, which has a marked effect upon the number of blossom buds produced in the cluster. Consequently, vineyard conditions in the spring materially affect crop production. This fact is significant in relation to tillage, pruning, and other cultural practices.

TILLAGE

Cultivation should be started before bloom. The vines which come out into leaf in the spring and develop a large amount of foliage in a short period need favorable growing conditions to produce a good crop. Where

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grape berry moth is present it is important to bury all grape leaves and berry moth pupae a week before the grapes bloom. This reduces the number of moths. Also, it takes less effort to weed the vineyard when this work is started promptly in the spring.

The following tillage procedure is favored in New York:[230] The first operation is plowing.* Probably the tractor, because of the steady pull, does a better job, especially at shallow depths. In plowing once each year, the furrows are turned to the vines. With rows eight feet apart, a bout to the row turns practically all the surface. Rarely should a vineyard be plowed deeper than four inches; most acreages will not permit a depth of more than three inches. The double-disc harrow often is a good tool to follow the plow, the frequency of use being, as a rule, one to four times a year. The object is to bring the ridged soil back to the normal level. Then, a heavy spring-tooth harrow, used at intervals sufficiently frequent to keep down weed growth, is used. After the soil has been leveled, the grape horse hoe set to pull away from the vines is run around each row. This operation cuts off the weed growth underneath the wires, leaving only a little close to the trunk, which is in turn removed with the hand hoe. Cultivation is continued until late July or early August, when the horse-hoe blade is reversed and a ridge is thrown up on each side of the vines. This serves to cover weeds and also prevents water from settling about the base of the vine during winter and early spring.

Another good procedure is, before bloom, to make a round with a one-horse plow, throwing the soil towards the vines. Then the middles are worked, using a plow on a clay soil and either a plow or disc on the lighter types. After bloom, cultivation is practiced frequently with a spike- or spring-tooth harrow, leveling the soil as the season advances. Where the soil is ridged, it can be pulled down with the grape- or horse hoe so that only a little hand work next to the vines is needed. When the soil is level, the small weeds under the wires may be smothered by throwing soil towards the vines. At the last cultivation on clay soils, just before seeding the cover crop, the soil is thrown towards the vines. The ridge should not be left excessively high but just enough for surface drainage and to make

* In New York the two-gang plow with long moldboards is favored. In Michigan the three- or four-bottom vineyard gang plow with about 12-inch bottoms is most commonly used. The three-bottom plow is used with eight-foot rows and the four-bottom with 10-foot rows.

In the initial step in turning under the rye cover crop, the soil is thrown toward the vines.

it possible to work near the plants in the spring without uncovering the roots. On gravel or sandy soils, a ridge is seldom necessary.

Choice of disc or spring-tooth harrow may depend greatly on the location of the upper roots and the soil type; an example will emphasize the point. On rolling loamy sand in Michigan,* the upper mat of roots on the crest in loose, soft sand reached up to about three inches below the surface. In the more loamy hollow, these roots were all more than six inches below the surface. A disc operated in this vineyard by the usual grower would be set to do a good job on the heavier soil and would not be reset for the sand. Even if reset, it is doubtful whether it could be operated so that it would not do much damage. Therefore, it would seem that the disc is a dangerous tool to use in vineyards on loose soils. The spring-tooth is less destructive on those soils, though less satisfactory on loams.

Near Sandusky, Ohio,[3,5] in controlling the berry moth by cultural means, the general plan is as follows: the soil is thrown to the vines at the last cultivation in summer, not later than August 15; no further cultivation is given until the next spring, the cocoons thus being left on the ground unprotected during winter; spring cultivation should bury the overwintered cocoons and keep them buried deeply until after bloom. A comparatively shallow covering of soil is sufficient to prevent the moths from

* Correspondence with N. L. Partridge, Michigan Agricultural Experiment Station.

coming out of the ground. The pest reaches the ground in fallen, infested grapes and in those discarded from the bunches in picking.

In Erie County, Pa.,[487] a light-draft three-bottom gang plow when drawn by a tractor required 39 per cent less time per acre than when drawn by horses. Using a single plow drawn by one horse, six times per row, cost more because of the large amount of man labor required to plow an acre. Using a single plow drawn by one horse to throw a furrow on each side of the row, after gang plowing, cost almost as much as to plow six furrows per row with a three-bottom gang plow drawn by tractor. On the average, it paid to use a tractor on farms of over 50 acres in crops. On smaller farms, it was cheaper to do all the work with horses. Horse hoeing and hand hoeing are two of the most expensive operations.

When the land is very flat and the rows are not ridged up a little to facilitate drainage it may be best to plow in the fall; also, where the land is heavy it works better in the spring following fall plowing. However, fall plowing should be delayed until normal leaf fall when the vines will no longer be stimulated into further growth. Where the soil tends to wash badly, plowing should be left until spring.

IRRIGATION

The irrigation of vineyards, in regions where it is necessary, does not differ greatly from that of other deciduous fruits (see under Bramble Fruits). After growth starts in the spring the vines are allowed to exhaust most of the available moisture in the root feeding zone and then the soil is wet thoroughly. This practice is continued until the fruit is nearly ripe. One should avoid irrigating during bloom and in the latter part of the ripening period. A late application of water, after the leaves have started to drop, is desirable.

FERTILIZER

Humus, Manures, and Cover Crops

Physical and chemical studies[504] of soils in north-central Ohio vineyards reveal these facts:

1. A favorable surface soil granulation or good state of aggregation has been destroyed in many vineyards by excessive cultivation and the lack of cover crops or manure over a long period of time.

2. Organic matter and total nitrogen, which are very closely related to aggregation, have been seriously depleted in many vineyards. Organic matter losses varied from 20 to 80 per cent, whereas losses of total nitrogen as high as 85 per cent were recorded.

3. The decrease in total exchangeable bases ranged from 18 to 76 per cent of the original amount assumed to have been present.

4. Losses of the individual fertility elements, calcium, potassium, and phosphorus are not as pronounced as the loss of organic matter and nitrogen but, in some cases, may become limiting factors, especially if sufficient organic matter and nitrogen are restored to the soil.

5. Only two vineyard soils out of 12 did not show a loss of exchange calcium. The amount of exchange calcium depends largely on the soil origin.

6. There is no consistent change, under the usual vineyard culture, of exchange potassium. Some soils originally contained more than others.

7. Except where there has been serious erosion and loss of organic matter, readily available phosphorus is equal to or higher in the vineyard than in adjacent undisturbed soil.

8. There has been no great change in soil reaction.

9. Less intensive cultivation and the use of manure or fertilizer with cover crops are recommended to restore and maintain soils in a more productive condition when they are to be used for growing grapes.

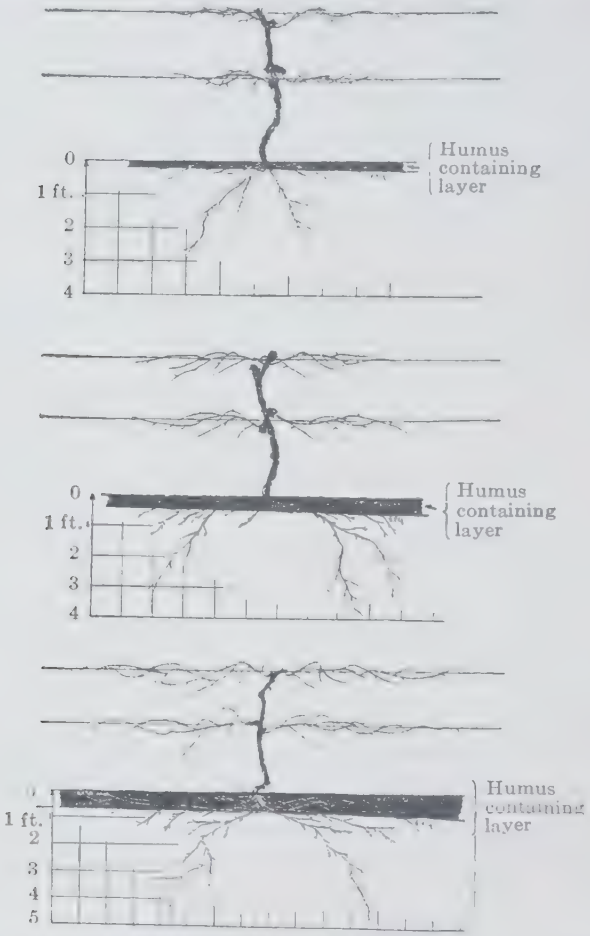
Manures or cover crops turned under aid in providing the humus necessary for good physical condition and moisture-holding capacity of the soil, and in supporting desirable soil organisms. Humus-supplying materials also contain amounts of fertilizer elements. Many growers have found it profitable to build up the soil for several years prior to planting, by the use of green-manure crops and farm manures. Grapes outlive the humus supply of most soils unless it is replenished. The humus content in many vineyards is much too low.

Some functions of green-manure crops are: to check growth in the fall, thus giving the vine time to mature its wood properly; to utilize nitrogen available in the soil after the vine has ceased growth, and prevent its loss by leaching; to hold snow and thus prevent deep freezing; and to maintain or improve the organic matter of the soil. A green-manure crop will help to prevent the topsoil washing away during heavy rains. If it is left standing over winter it will help prevent erosion, and will hold many of the grape leaves which add organic matter to the soil.

A humus-supplying crop should be sown in late summer. If the distance between rows allows it, it is convenient to use a grain drill to sow the cover crop, rather than a cyclone seeder as no seed will be sown under the vines. A cover crop there might interfere with good air circulation, and in the case of rye it is difficult to turn it under properly when sown close to the wires.

Under some conditions it is best to use a crop that winterkills, under

other conditions one that does not, and under still other conditions to use both, either combined or with the crop that winterkills turned under before the overwintering one is sown. Cover crops that live through the



Diagrammatic representation of growth on soils with different humus-containing layers, without fertilization. (*Top*) Layer less than 5 inches thick. The thin soil limits the bulk of feeding roots, and the growth of the canes is much reduced. (*Center*) Layer about 6 inches thick. This depth permits a greater development of roots than the thinner soils. (*Bottom*) Layer about 10 inches thick. The thicker soil permits the development of a larger bulk of roots, particularly in the humus-containing layer and in the soil just beneath it. The growth of the canes is also much greater, corresponding to the larger bulk of the root system. (Courtesy, N. L. Partridge, Michigan Agr. Exp. Sta.)

winter may reduce the early-season growth of the vines as well as the later growth, unless the cover crop is turned under early. A similar result may follow from an attempt to increase the humus supply by sowing a cover

crop in the spring in the vineyard, though, in this case, the early-season growth of the vines is not involved. When the vine growth is checked too early, the adverse effect also shows in the fruit. Unfortunately, the average grower in northern regions does not commence cultivation early enough when an overwintering crop is making a good spring growth. Where the winters are more open, in the southern areas, it is likely that the overwintering cover crop (which will continue to grow during the dormant period of the vine) will be very valuable as a source of organic matter and a means of checking soil erosion. The item of prime importance is that the cover crop should not delay spring tillage enough to check growth or to prevent the covering of the berry-moth pupae where this insect is present.

Oats (two bushels per acre) are a fairly good cover crop on soils where they can get a good start. This crop may not be the best to use on sandy soils lacking in humus. Millet, like oats, winterkills. Neither of these crops hinders early-season growth of the vines. On moderately fertile soils, millet (20–30 pounds per acre) may make more growth than oats; however, millet seed is usually more expensive and more difficult to obtain. Oats and some millets make strong growth in the fall and may therefore be objectionable at harvest time. However, they may be knocked down with a stone boat or by running over them once or twice with a disc. On the other hand, oats and millet are killed by frost, and there is no temptation to delay spring cultivation as in the case of rye which makes its heavy growth in spring. It is essential that spring cultivation be done early. A delay gives more material to work under, but owing to its more mature condition it will break down slowly, causing drying of the soil and reducing the soil's nitrate content, thus adversely affecting cane growth.

Buckwheat (40 pounds per acre) will grow on soil too poor for many other cover crops and makes a rapid growth in the fall, thus tending to check the growth of the vines and prevent them from entering the winter in too succulent a condition. Some growers use a mixture of a bushel of oats and a peck of buckwheat per acre. Soybeans (6–8 pecks per acre) also winterkill and, when inoculated and sown in late June (soon after bloom), make an excellent cover crop on soil which is too poor for oats. Vetch overwinters, makes a good early growth, and is a legume; it requires inoculation at the outset, the seed may be expensive, and sometimes the

seed does not germinate well. Seeding at the rate of one bushel of rye to 20 pounds of hairy vetch is a satisfactory combination in some cases, as is barley or winter wheat at the rate of 1½ bushels per acre. Most clovers start too late in the spring to give a good growth by the time spring plowing should be done.

In using humus-supplying crops it is a good plan to seed alternate rows from year to year, largely for the purpose of avoiding wet conditions when picking.

In Erie County, Pa.,[487] the vineyards on the lighter soils that were seeded with a cover crop yielded 13 per cent better than did those that were not seeded. Only a part of this increase was due to cover crops, however, because more fertilizer was applied to these vineyards.

Where manure can be obtained conveniently or at reasonable cost, 10 to 30 tons may well be applied per acre and incorporated in the soil. Barnyard manure has increased yield more than has chemical fertilizer in Ohio experiments, but this has not always been true in New York, as is brought out in later discussion. When poultry manure is used, since it is richer in quickly available nitrogen, only one third to one half as much is needed.

Use of Chemical Fertilizer on Grapes

Experiments on the Use of Fertilizer

New York. Probably the oldest and most complete fertilizer experiment on American-type grapes is the one begun in 1909 at Fredonia, N. Y.[219]

Nitrogen proved most helpful. It improved the vigor, increased the yield, and gave larger berries and bunches. Potash gave more pronounced results than did phosphorus, though the latter was more beneficial to the green-manure crops. Potash caused earliest ripening of the foliage. Even when the same number of canes was tied up, fertilizer produced a decided gain of fruit. The foliage, after the first few years, was of better color and size when nitrogen was applied; that on vines receiving phosphorus and potash ranked second; with the check a poor third. During the first few years, the fertilized vines matured their fruit earliest. This was less evident later, except for vines receiving phosphorus and potash. Bunches on vines receiving phosphorus and potash, though superior to the checks, were not

the equal of those on nitrogen fertilized vines. Bunches from the checks were small and loose, with berries below average size. The sugar content was higher on the checks, but the general appearance of the fruit was inferior to that from the fertilized vines. Young vines that were not taxed by large crops, not seriously injured by insects, and that had not depleted the soil of the chief elements of fertility suffered the least. In a year when conditions were such that many vines were lost, the losses were mostly on areas without fertilizer or manure. A fertilizer high in nitrogen was recommended, but before applying it, fundamentals of good care, drainage, cultivation, cover crops, control of insects and diseases, and proper pruning should be attended to.

Long-time tests with manure, 5 tons per acre annually, on the lighter soils (Dunkirk gravelly loam) showed no increase in fruit and no gain in cane and leaf growth. On Dunkirk clay loam, however, the response was comparable to the nitrate of soda treatment. Possibly a larger application on the lighter soil would have given a like result. In both cases the manure was purchased and probably would not rate so high as the better farm manures. On the heavy soil there was a greater tendency to excessive cane production from manure than from nitrate of soda. The excessive use of stable manure caused an out-of-balance condition which resulted in low yield, poor quality, and an amount of cane and leaf in excess of all needs.

MICHIGAN. The Concord vineyard with vines which annually yield $2\frac{1}{2}$ to $3\frac{1}{2}$ pounds of prunings per vine approaches most closely the ideal.[359] It is capable of producing annual crops of $3\frac{1}{2}$–$4\frac{1}{2}$ tons per acre. If its vigor is much greater, though its potential productivity is greater, there is increased hazard that the vines will become overvegetative and hence less fruitful. Excessive growth at certain periods is detrimental. Neither the current crop nor the fruiting canes for the next year can mature as well when much fall growth is taking place. Another critical time is during bloom and fruit setting. Set is lessened if the growth is either very rapid or weak at this time. When the spring growth is weak, the leaves on the main shoots are small and no laterals develop. If the leaves are small and few at bloom, the blossom clusters and ripe bunches are small. Within limits, the greater the vigor and leaf area, the larger are the blossom clusters. If growth during the bloom is too rapid, the flowers set poorly and the bunches are loose or straggly. The blossoms under such conditions apparently do not receive enough food to develop normally,

probably because the rapidly growing tips of the shoots and laterals use these materials. The undesirable effects of late growth are due to the loss of the materials which support this unwanted growth instead of being used for maturing fruit wood and buds. Profitable increases were obtained from nitrogen. The increase in yield from phosphate or potash did not pay for its application. There were differences in the return from equal applications of fertilizer to soils of different types. The stronger vineyard growing on Fox sandy loam gave lower returns per unit of nitrogen than did the weaker one on Plainfield loamy sand.

Advantages of any fertilizer in increasing the percentage of total solids or hastening maturity were not conclusive.[364] The juice from unfertilized vines was higher in total solids than that from plots receiving nitrogen, either alone or combined with phosphorus, potash, or lime. The use of nitrogen somewhat delayed maturity where the pruning was carefully balanced to vine vigor.

Nitrogen influenced the growth and yield of vines on areas that received no fertilizer as far as 15 feet from the plot margin.[365] In fertilizer tests, record vines should be at least 20 feet from the plot margin. Variations in thickness of the humus layer of the surface soil influenced vine growth and yield more than did any other soil factor. Yield on humus layers 3–6 inches thick was twice that on layers less than three inches thick. Somewhat smaller increases occurred when the layer was 6–12 inches thick. Most of the increased yield from fertilizer was associated with greater growth, with some indication that vines receiving nitrogen alone were slightly more productive than unfertilized vines of equal growth. Vines given phosphorus and potash besides nitrogen were slightly more productive than vines of equal vigor with nitrogen alone. Fertilizer produced relatively small increases the first year, the greatest benefit coming later from increased vine growth. It was found impossible to increase the yield of vines on the thinner soil by commercial fertilizer to where their yield equalled that of unfertilized vines on soils with a thicker surface horizon.

The culture of the Campbell Early must be adapted to secure more vigorous shoot growth than is necessary for Concord.[360]

Missouri. In general, the results (including those with 26 cooperators) indicated that on most Ozark soils, nitrate is useful on mature vineyards at the rate of 150–200 pounds per acre, and manure should be used more

to increase or maintain the humus content of the soil than to increase the yield.[207]

ARKANSAS. No fertilizer treatment gave any outstanding results over a five-year period, except that nitrogen fertilizer and manure seemed to produce an over-vegetative condition.[517]

OHIO. A four-year average[260] of untreated plots of Concord on moderately heavy soil was 5,276 pounds of fruit per acre; nitrate of soda, 250 pounds per acre, produced 5,312 pounds; at the rate of 500 pounds the yield was 5,935 pounds; and 10 tons of manure gave an average yield of 6,321 pounds of grapes per acre. Manure also resulted in the highest yield in a Catawba vineyard 60 years old on Middle Bass Island. This again emphasizes the importance of providing organic matter in the soil for grapes.

Demonstrations[257,258] of the effects of nitrogen* and phosphorus emphasized that the type of soil affects the profitable use of fertilizer. On clay soils, the yield was increased 9 per cent in one vineyard, 12 per cent in another, and 32 per cent in a third. On gravel soils, it was increased 28 and 31 per cent, respectively, in two vineyards where annual applications were made. The mixture gave greater increase in yield on a sandy than on a clay soil. In Lake County (a gravel soil, clean cultivated and without a cover crop), the yield was increased 35 per cent by annual applications of the fertilizer. On clay soil near Geneva, Ashtabula County (cultivated each year and a cover crop of rye sown during the summer or late fall), chemical fertilizer did not give a substantial increase until the third season. The average increase for three years was 23 per cent.

No significant effect was found[270] from the use of fertilizer on pectin soluble in cold water, pectose or protopectin, and pectin materials in the middle lamella, in the fruit of Concord. Soluble pectin increased from July 14 to final harvest, August 27, with the period of rapid increase occurring from July 30 to August 13. Insoluble pectic materials, however, decreased during the entire period, which indicates a conversion of insoluble to soluble forms during ripening.

ONTARIO. At Vineland[252] the organic matter and green-manure plots were the only ones returning an increase in yield sufficient to pay for the materials applied. This indicates the importance, especially where manure

* 250 pounds of nitrate of soda and 250 pounds of superphosphate.

is not readily obtainable, of encouraging the growth of green-manure crops by proper fertilizing. The mineral fertilizers used to promote the growth of green-manure crops are eventurally returned to the soil in a highly desirable organic form.

Results at Jordan showed little benefit from surface applications of phosphorus and potash, because the roots did not have access to the minerals applied in this way. Minerals should be applied deeply, and in the fall so that the plant has time to overcome the shock of root cutting before the start of the next year's growth.

California. California vineyards[519] have shown on the average about a 10 per cent yield increase resulting from N application. The addition of P and K have tended to depress the effect of N and, significant yield increases have not resulted from the addition of P and K. Nitrogen has a marked deleterious effect on the color development of Tokay, which decidedly limits the amount of N which can be used if these grapes are to be sold for table use. The addition of P and K to the N has had no appreciable effect in overcoming the diminution of color brought about by N. The sugar content was lowered slightly, and the acidity was increased slightly and to about the same extent by either N or NPK fertilization. The pruning-weight changes largely correlate with the yield changes and serve as checks on harvest records as well as to indicate incorrect pruning practices. The berry size does not seem to be appreciably influenced by the fertilizer applied. On the average, moderate nitrogen applications will at least pay the cost of the fertilization and in many instances will be quite profitable. Phosphate and potash applications added to the nitrogen, on the other hand, seem to be slightly detrimental.

General Recommendations on Fertilizing Grapes

The foregoing work in a number of places indicates that different responses are obtained from the use of fertilizer under different conditions. It also shows some fundamentals which should be borne in mind when considering the use of fertilizer.

A general guide for American-type grapes is to apply 250 pounds of a quickly available nitrogen fertilizer, such as nitrate of soda, each year in early spring. Superphosphate, 300 pounds per acre, and muriate of potash, 75 pounds per acre, are normal rates when needed. The use of cover crops is significant, and attention should also be given to their fertilizer require-

ments. Good methods with respect to fertilizer and pruning go hand-in-hand; improper pruning will offset possible responses from the use of fertilizer. This statement is true for a number of other practices, such as disease and insect control. Fertilizer should be used primarily as a supplement to, not as a substitute for, good culture. It is highly important that applications of fertilizer be made in accordance with the growth status of the vines.

Application of borax, about 10 pounds per acre, is helpful in some cases to avoid chlorosis.

COMPANION CROPS

Ordinarily, it is probably best to avoid companion crops in a vineyard, but the financial return is often important, particularly because there is a considerable expense outlay before the vines bear. Garden crops that are small in size and require cultivation until late summer, or strawberry plants for propagation, sometimes can be grown profitably between rows of young grapes. Few grape growers with large acreages attempt to interplant with any kind of crop.

THE GRAPE TRELLIS AND ITS CONSTRUCTION

General Considerations

The trellis for American-type grapes is usually erected in the spring of the second year. The vines usually are allowed to trail along the ground the first year. If posts are set and wired soon after planting, the training of the vine can be started immediately. The young vines will be out of the way of implements and the vineyard is more easily kept free of weeds. These advantages may outweigh spreading the expense of planting and posting over two years.

Tying the shoots to stakes is frequently but not always necessary. Staking encourages a straight trunk, aids in establishing the vine to the top wire, avoids "stringing up," and shortens the non-bearing period, especially in the Kniffin systems.

In one method of training, a grape twine is tied tightly to the one-bud cane and to the wires above the vine. Tying to the two-bud cane which is to produce the trunk may result in girdling when the trunk grows larger. Usually both buds on the two-bud cane start growth. The weaker of the two should be removed when 1–2 inches long, together with any surplus

shoots that may have come up. As the vine grows in length it is twisted loosely about the twine, this operation being necessary several times during the season. When the cane reaches the top wire (Kniffin system), which may take two years, it is cut off just above the wire and tied tightly to it. If the cane is too short to reach the top wire the first spring after planting, cut it off above the last good bud. Tie below this bud, draw the cane up tight and straight, and tie to the top wire.

If posts are not set the first spring they should be set in the fall so that the vines can be tied up the next spring before any growth starts. If the first year's growth has been very weak the vines may again be cut back to one two-bud cane and a one-bud stub. Some growers cut back to 2–3 buds at the end of the first year regardless of the amount of growth the vines have made. However, where good growth has been made nothing is gained by this delay in training. In fact, fruiting is delayed without any compensating benefit to the young vine.

The trellis is a big item of expense in the grape grower's budget. Nevertheless, it is usually cheaper in the end to erect a good trellis which will remain for a long period than frequently having to replace a poor one. After a number of years, even with a good trellis, the need always arises for replacing some of the posts, renewing the wires or fixing broken ones, rebracing end posts, and various other details.

Table 5

TIME SPENT PER ACRE TO MAINTAIN TRELLIS AND VINES AND TO PRUNE AND TIE VINES. 552 VINEYARDS[395]

Area	*Total Hours per Acre*	*Percentage of Total Time**
Michigan	31.2	64.9
North East, Pa.	32.6	62.7
Niagara Co., N.Y.	33.8	64.3
Chautauqua Co., N.Y.	38.8	63.5
Girard, Pa.	40.6	71.5
Arkansas	46.3	57.3
Finger Lakes, N.Y.	53.4	66.8
Hudson Valley, N.Y.	72.3	47.8
Average	40.1	62.6

* Percentage of total cost or time of growing grapes excluding the cost and time of picking, harvesting, and marketing.

To keep the trellis in repair and to prune and tie the vines requires, on the average, 40 hours of labor per acre, Table 5. Other labor, such as hauling and spreading manure, plowing, cultivating, hoeing, spraying, etc., amounts to 63 per cent of the total labor in the vineyard up to picking.

Posts

Kinds of Posts. The posts should be strong and durable and commonly are chestnut, locust, cedar, oak, osage orange, catalpa, iron, or steel. Ordinarily, chestnut, white cedar, and oak posts last about 10 years and red cedar slightly longer. Locust posts usually survive for 15 years or more. Creosoting wooden posts prolongs their life and makes it possible to use somewhat lighter ones. Wooden posts (e.g., cedar) are commonly 5–8 inches in diameter and 7–9 feet long for the end posts and at least three inches in diameter and 6–8 feet long for the interior posts, allowing for driving into the soil. The length of post needed depends, in part, on the system of training. The Kniffin systems, for example, require longer posts and higher top wires than do upright systems. Steel posts are easily driven into the ground. With some steel posts, the wires may be run directly through holes previously bored. Usually, however, it is better to use contrivances that permit freer stretching of the wires. Driving the steel posts with the holes in them paralleling the rows permits the use of staples to support the wires. It is probable that, all things considered, the steel or iron vineyard post is the most economical in the end.

A common plan, though often a poor one, is to buy fence posts for vineyard use. About 18 inches are driven into the ground and 4–4½ feet left aboveground. The maximum height of the top wire with usual fence posts is not sufficient for best results in the Kniffin systems.

Spacing of Posts. This is largely determined by the distance of planting. As a rule, two, three, or four vines occur between the posts. If, therefore, the vines are set eight feet apart in the row the spacing for the posts is usually 16, 24, or 32 feet. In general, when there are three or four vines between the posts, firmer posts and heavier wires are advisable than when there are two vines between posts.

Bracing End Posts. Perhaps the oldest method is the use of a rail or scantling from another post set about eight feet away in the row. The brace reaches from a point about a foot aboveground on the second post to within 18 inches of the top of the end post. To complete the bracing a

Method of bracing end posts by wire attached to a "dead man" (log or stone buried in ground).

guy wire is passed from about six inches below the top of the second post to a short distance from the ground on the end post. This method is one of the strongest. The cost of scantling for braces, and the extra post, are factors against its more general use.

Another method is to anchor or "guy" the end post by a wire extending from about the height of the top wire to a "dead-man" buried $3\frac{1}{2}$–4 feet deep and 4–5 feet from the post. The guy wire may be attached to an iron rod, the end of which is bent and set in cement. The lower end of the wire often is fastened 24–30 inches from the post, but at this minimum distance there is a decrease in the purchase. Besides the small original cost of setting these guys, they furnish strong support to the posts while they last. The wires, however, are a nuisance in tillage. The implements will not only hitch into them, sometimes breaking them off, but the wires rust and break, and it is hard and expensive to replace them. Also, the head rows are difficult to keep clean.

A good brace is made from 4 × 4 timber, notched to fit the post halfway up from the ground and extending obliquely to the ground, where it is held by a 2 × 2 stake. The chief objections are that wooden braces often cause the end posts to pull out of the ground, and in many cases they rot at the lower end so that the post lacks support.

Still another method is to set the end posts in cement. The holes are made as deep as for the other methods, but the bottoms are cut out to twice the usual diameter. This gives the cement and post more of a purchase on the surrounding soil. Notches are cut with an axe on each side of the butt end of wooden end posts to enable the cement to hold the post firmly when it sets. When the cement is mixed with sand and rubble in the proportion of five parts of sand and rubble to one of cement, one bag suffices for about four holes. About two feet of this concrete in the bottom of the hole will hold the post. To prevent wooden end posts from rotting, the hole may be filled slightly aboveground. With the end posts set in cement the trellis is neat in appearance and the head rows are easily kept clean, but on certain soils these end posts heave badly.

Depth of Posts. The posts may be driven or set in holes dug for them. Interior steel posts are driven into the soil very easily. The end posts should be set at least two feet deep. On sites where heaving is not severe, a depth of 18 inches suffices. At first the posts, except those in cement,

Method of bracing end posts with stay posts.

are often permitted to stand somewhat higher than necessary so that they may be driven deeper later. The butt end of such posts should be "sharpened" before placing in the holes.

Wires

The number of wires used and their location depends on the system of training; as a rule, it is two or three for each system, though some systems require four wires. The sizes of wire in common use in vineyards are Nos. 9, 10, and 11. No. 9 is the heaviest. The number of feet per pound of galvanized wire is: No. 9, 17.95 feet; No. 10, 22.33 feet; and No. 11, 27.34 feet. Another estimate, in feet per ton, is: No. 9, 34,483; No. 10, 41,408; No. 11, 52,352.

With a three-wire trellis, approximately 15 pounds of No. 10 wire are required for 100 feet of row. With rows nine feet apart about 725 feet of No. 10 wire are needed per acre for a three-wire trellis. About one third less suffices for a two-wire trellis. These figures allow for some bracing at the end posts. For the Kniffin systems it is unwise to use wires lighter than Nos. 9 or 10. Sometimes No. 9 is used for the top wire and No. 10 for the lower. When the system requires three wires, Nos. 10 and 11 are commonly used.

Galvanized wire resists rusting and thus prolongs usefulness, as well as affording suitable material for the vines to cling to. Annealed wire is not so widely used as formerly. Self-tightening wire which is kinked or waved in long, open, flat spirals avoids the necessity of stretching to avoid sagging; but, in practical use, it is inferior to galvanized wire. Copper wire is suitable, except for the high cost.

The wires are placed on the windward side of the posts or on the uphill side. Fastening to the end post is commonly done by winding the wire around the post and looping it firmly about itself.

To stretch the wires taut a wire-stretcher with block and pulley may be used. A large hook may be used to hold the wire tight. Many simple devices are used to tighten the wires. A common one is a block of hard wood 1½ inches square and 8–9 inches long with a ¼-inch hole bored through the center. The center portion may be turned on a lathe to facilitate winding. The wire is passed through the hole in the block and wound about the rounded center piece. A monkey-wrench is used to tighten the wire. The squared part of the block is held tightly against the post and

Four methods of wire tightening. (*Top, left:* Large iron hook. (*Top, right:* ½-inch bent iron bar. (*Bottom, left:* Square wooden block. *Bottom, right:* Iron reel. (Courtesy Hort. Exp. Sta., Vineland, Ontario.)

prevents unwinding. In another method a small iron reel is fastened to the end post directly opposite the hole bored in it for the wire. When the wire is strung it is passed through the hole, made fast to the axle of the reel, and tightened by turning the reel with a detachable handle. A small "dog" attached to the outside of the reel prevents it from unwinding.

In some cases the wires are passed through the interior posts. As a rule, they are fastened to the interior posts by means of staples. The staples should not be driven too tightly, and so permit tightening of the

wires when necessary. The staples are commonly 1–1½ inches long according to the hardness of the wooden posts. About 10–12 pounds of staples are required for an acre of a three-wire trellis.

The wire must be slack in the fall; otherwise, it and the end posts are subject to an undue strain when the taut wire contracts during cold weather, perhaps breaking the wire or loosening the posts. Tightening the wires is done to good advantage after pruning, when the old ties have been cut and the vines are free from the trellis. Sometimes this is done by using heavy pliers to pull the wires from one end of the row and enable them to be made more taut by winding around the end post and then repeating the operation at the other end of the row.

One method of handling the wires in the fall is as follows. Against the end post a stay post is set that is six feet long and extends from the ground to a point about four feet high on the end post. This stay post is attached temporarily, and loosening it in the fall merely requires raising the end of the stay post next to the end post which can then sag and slacken the wires. The next spring, before the vines are tied but after they are pruned, the wires can be tightened by putting the stay post back in place on the end post, and by using a wire-stretcher.

Lightning running along the trellis wire sometimes kills most of the vines in a row. In some areas, trellis wires are grounded at every wooden post or two to prevent such losses. Since metal posts are conductors, they need no grounding.

TRAINING AND PRUNING THE GRAPE

Purposes and Principles

Pruning is classified under two headings, training and pruning proper. The former is concerned primarily with regulating the vine and the latter with regulating the crop. Some chief purposes of training are to establish the skeleton or scaffold body of the vine and to ensure systematic distribution of parts on wires so that the vines are most conveniently managed in spraying, tillage, pruning, harvesting, and other operations. Proper pruning regulates or encourages good annual yield, size, and quality of fruit. Growers usually consider both operations, i.e., training and pruning, as pruning, and with some justification, for growth and yield are interrelated. However, in the grape a distinction between training and pruning is

significant because there is, for example, a number of different systems of training.

The parts of a vine, in relation to training and pruning, are these:

Trunk: The main unbranched body, stalk, or stem of the vine.
Arms: The main branches or extensions of the trunk.
Head: The region of the trunk from which branches arise.
Old wood: Any part of the vine older than one year.
Shoots: New leafy growths developing from buds. They are called shoots during the growing season. After the leaves fall they become canes.
Canes: The dormant shoots grown the past year or shoots that have become woody.
Laterals: The side branches of a shoot or cane.
Spur or renewal spur: A cane cut back to a short stub usually 1–2 buds long to produce next year's fruiting cane at a desired location.
Nodes: The joints on shoots or canes where leaves or buds are attached.
Internodes: The wood of shoots or canes between the buds.
Eye: The compound bud at each node on a cane.
Primary bud: The largest and strongest bud of an eye.
Secondary bud: The smaller bud of an eye.
Suckers: The shoots arising from below ground.
Watersprouts: The shoots arising from buds along the trunk.

Season of Pruning the Grape

Dormant Pruning. The chief pruning, and usually the only pruning, of grapes practiced each year is commonly done in commercial vineyards, without much regard to possible variation in effects, in the period ranging from soon after leaf fall until late spring.

In Missouri,[207] the highest yield occurred from the vines pruned in January, and it was considerably more than from those pruned in December or in March. (January pruning in Missouri is comparable to pruning a month or so later, probably early March, in some states farther north.)

Severe winter temperatures often occur in early March in western New York,[224] therefore, more killing of bud and cane will show after this period. Hence, for acreages that could be pruned in 2–3 weeks, delaying the pruning until after the low March temperatures, is suggested. A seven-year average[220] showed a slight gain in yield from spring-pruned vines, as compared with winter-pruned ones. This was probably due to the ability of the pruner to select the best matured canes in the spring after they had been subjected to the low temperatures of winter.

One drawback to pruning soon after leaf fall is that some poorly matured canes may be left even in a year favorable for fruit and cane maturity. Several hard freezes may be required to distinguish the well matured from the soft canes. Good yields have been obtained when a mild

winter followed fall pruning. If the pruning is done very early after leaf fall there is a possibility of the canes drying or freezing back one or two buds. Pruning should not be done on very cold days as the canes are then very brittle and those left may be injured in pulling out the brush. Since Concord is sometimes severely winterkilled in bud, it is preferable to delay pruning until after the low temperatures of winter, especially after a year unfavorable for maturing bud and wood. With large acreages this is impossible unless enough men are available for pruning. Pruning in the spring (but before growth starts) enables one to prune to canes in the best condition and with the least number of injured or dead buds.

There is little transfer of carbohydrates from the canes to the roots, or vice versa, during the dormant season. So, within reasonable limits, the effects of time of pruning (and taking of cuttings) are not affected by this factor. Possibly, however, pruning after active sap flow has led to the translocation of food reserves to the canes may result in some loss in the parts removed.

"Bleeding" of grape vines commonly occurs in the spring, particularly after late pruning. This causes many growers, particularly amateurs, great, but usually undue, concern, for the bleeding causes no serious damage to the vine when the usual cuts are made. Damage from bleeding has probably been overemphasized (except perhaps in the case of unusually large cuts). The term "weeping" has been suggested as more appropriately describing the condition than does the term "bleeding"; and "tears" seldom cause serious ill effects. (The term "weeping" is introduced here for illustration, not as an acceptable substitute for "bleeding.") When pruning has been delayed or neglected, it is generally better to prune late in the spring, even though the vines bleed, than to leave them unpruned. When the leaves appear, bleeding usually stops.

At Meridian, Miss.,[307] with the muscadine grape, no significant differences in yield resulted between vines pruned soon after leaf fall and vines pruned just before the buds begin to swell in spring. The spring pruning causes severe bleeding whereas early winter pruning results in little or no loss of sap. Chemical and refractometer analysis indicate that the sap consists almost entirely of water. Yield records confirm the conclusion that no great amount of plant nutrients is lost through bleeding.

Summer Pruning. This should be discouraged, except to remove suckers. The purposes advanced by inexperienced growers for summer

trimming are to reduce the amount of growth, to permit better penetration of sunlight, and to prevent rotting of berries.

Some objections are that the vine is weakened; undesirable laterals are produced and the resulting dense growth interferes with air circulation; the maturing of wood is delayed; the grapes may fail to develop the best flavor and color; sunscalding of the berries sometimes results; some of the best fruiting wood for the next year's crop may be interfered with; hence, it is not an adequate substitute for proper winter pruning and for spraying. Spraying to maintain healthy foliage, and summer pruning to remove part of it, are opposite procedures. The carbohydrate and other materials which are produced and used by the plant in the development of roots, top, and fruit, occur in the foliage. Reduction of the leaf surface, whether by summer pruning, disease, or insects, adversely affects both plant and fruit. Grapes, unlike tree fruits, do not need direct sunlight to develop color. They color well in the dense shade of the leaves, provided those leaves are healthy and other factors are not limiting.

In New York,[307] summer pruning was commenced June 29, half the terminal growth of the fruiting canes being removed. On July 19, or three weeks later, the new shoots from the terminal buds of the pruned canes were broken off. This was repeated at another interval of three weeks, or on August 9. Summer pruning delayed maturity and decreased the sugar content of the grapes. The later maturing varieties showed a greater percentage decrease in sugars and a more striking difference in maturity.

A severe type of summer pruning was used for a special purpose on a few mature-age vines in Ohio. The vines were not bearing a crop because of low temperature in the spring. In August, these few vines were pruned to demonstrate to visitors the method of winter pruning; that is, the vines were pruned as if the season was winter instead of summer. The effect was so drastic that several years were required before the vines resumed normal vigor, and, in fact, some mortality occurred.

When the shoots are in the way of cultivation, tying them up off the ground is better than severe summer pruning. In fact, the inexperienced grower may consider the growth as much too thick; whereas this really may not be the case.

SUCKERING. This is the removal of all shoots that appear on the trunk of the vine at or below the surface of the soil. These suckers bear little or no fruit, and hence grow vigorously, appropriating food materials which should go to the vine. Much time and expense are saved if suckering is done carefully during the first four or five years of the vine's growth. After

the fifth year very few suckers will be produced from vines that were carefully suckered when young. Vines on which the work is carelessly done will produce suckers every year. Suckering should be done early in the summer before the shoots become hard and woody. Old suckers are more difficult to remove than young shoots and, if imperfectly removed, the remaining part becomes an underground spur which is a perennial source of trouble.

Systems of Training Grapes

Classification

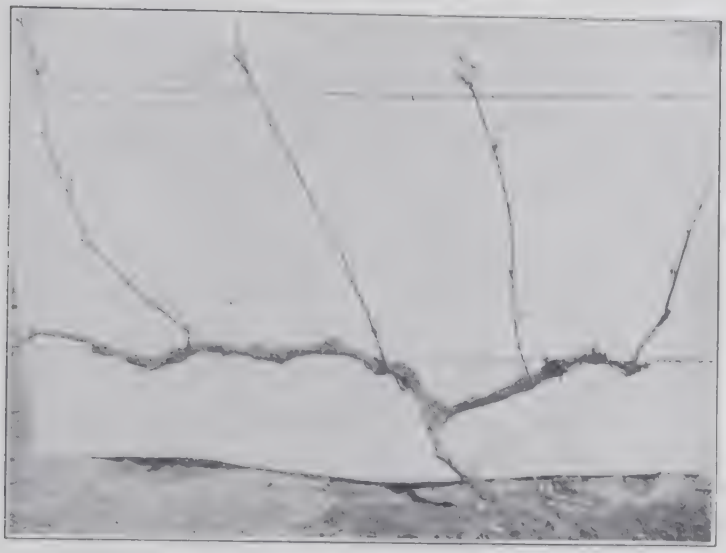
There are a number of definite systems of training American-type grapes. Some varieties respond better to certain systems than to others. In too many commercial vineyards there is no definite system of training, which is unfortunate, as any system ensures uniformity of work and appearance and simplifies handling in cultural operations, particularly pruning.

The following classification can be made of habit of shoot growth and system of training: Shoots upright—Chautauqua, High Renewal, Fan; Shoots drooping—Single-trunk, four-cane Kniffin,* two-trunk, four-cane Kniffin, single-trunk, six-cane Kniffin, Umbrella Kniffin, Y-trunk Kniffin, Munson, Hudson River Umbrella.

In the drooping method, the growing shoots are not tied but droop throughout the growing season. Since the shoots need not be tied, some labor is saved. Vines with drooping shoots can be tilled more easily and with less injury. The drooping shoots also protect the canes from sunscald. In the upright method, two or more canes or arms are laid off to the right and left and carried along a horizontal wire, or they are carried obliquely across two or more wires. As the shoots grow upward, they are tied to wires above. The upright methods fall into two classes, characterized by the terms "cane renewal" and "spur renewal," according to the manner in which fruiting shoots are obtained from the vine. Cane renewal is further divided into "high renewal" and "arm renewal."

Best results are likely to be obtained with vigorous vines of Concord when the shoots are allowed to droop, and with vines more capricious in

* Named after Wm. Kniffin, Clintondale, N. Y. He developed the method about 1850.



Chautauqua system of training, after pruning.

growth, like Catawba and Delaware, by upright methods. It cannot be said that any one system of training grapes is best suited to all conditions.

Systems with Shoots Trained Upright

CHAUTAUQUA SYSTEM. This system is used largely near Westfield, Chautauqua County, N. Y., and to some extent in Pennsylvania, Ohio, and a few other states.

More or less permanent arms are established and maintained, the canes are tied in an upright position on the wires, and the shoots are tied in the summer.

Two wires are commonly used, but three are more desirable, especially on wind-swept sites, and to eliminate stringing up (the use of twine to bridge the space for a cane that is too short to reach the upper wire). The lowest wire usually is 18–20 inches from the ground. When only two wires are used, the second is spaced about 34 inches above the lower. Sometimes the second or top wire is spaced closer than 34 inches for the first few years and then raised to the required height. When three wires are used the upper two are about 20 inches apart.

A cane for the future trunk is tied to the lower wire as soon as practicable. Shoots from this cane, extending horizontally right and left, are tied to the wire. All others are removed. The head of the vine should be

below the lower wire, rather than at or above it. While the trunk is small, all but two or three canes and an equal number of spurs situated on or near the head should be removed. The canes are carried obliquely to the middle or upper wire as the vigor of vine permits.

After the trunk and arms are established and the vine is bearing well, the arms on the lower wire are shortened to within three feet of the head, all but three or four canes (or enough to provide an adequate number of buds per vine) cut from them, and spurs which may furnish the fruiting canes for the next year left at intervals along the arms. The canes retained should be long enough to reach from the arm, when tied to the lower wire, to the middle and upper wires. All suckers are removed.

Renewal of the arms is practical because the canes of the past year, located nearest the head, often produce well matured wood of sufficient length so that the old arms may be entirely cut away, and the cane of two years previous laid down to the wire as an arm, with the past year's growth furnishing the fruiting canes. For trunk renewal, a well grown shoot coming from the ground is selected and tied loosely to the old trunk. Then, as soon as the framework is attained, the old trunk is cut away. In this renewal there need be little loss of crop.

Some merits of this system are: it is well adapted to regulating the number of canes according to the vigor of the vine; relatively short posts may be used; and, it is adapted to certain varieties capricious as to growth habits.

Some objections are: summer tying is required; the best canes often develop at extremities where they cannot be used to best advantage; some fruit is produced near the ground and becomes dirty; low growing shoots are injured in cultivation and interfere with cultivation; the canes often are blown down in summer, especially as the fruit approaches maturity, and require retying (if not retied damage to woody and shoot parts or dirty fruit results); stringing up canes is often necessary; it is not well adapted to spraying with fixed nozzles; pruning is comparatively slow; taller posts, as required for the Kniffin systems, may be the better investment for Concord; and, often the canes left for fruiting are too short for best results with Concord.

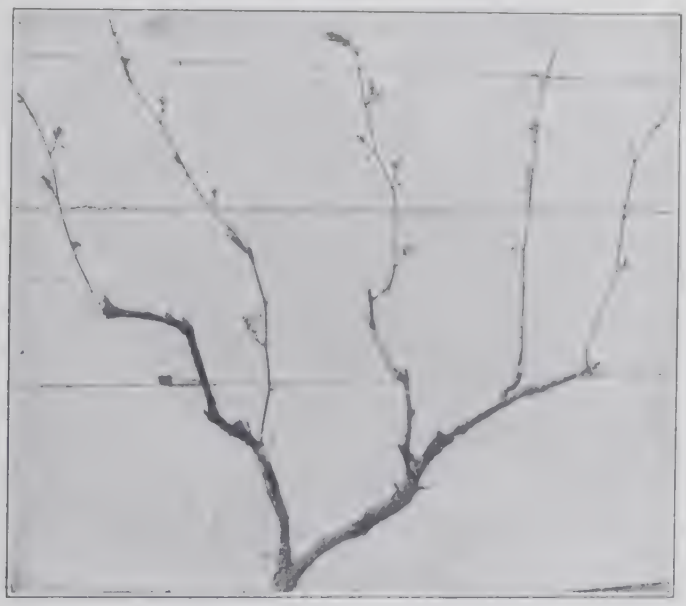
High Renewal System. This system, particularly the Keuka High Renewal, is used largely in the Finger Lakes area, and chiefly for Catawba and Delaware. Usually, three wires are used, the lowest 18–20 inches from

the ground, and the others at intervals of 20 inches higher. The trunk reaches just below the lower wire, with canes to the right and left. These canes are tied to the lower wire. As the shoots grow in the spring they are loosely tied to the other wires with rye straw or soft twine, which is called "green," "straw," or "summer" tying.

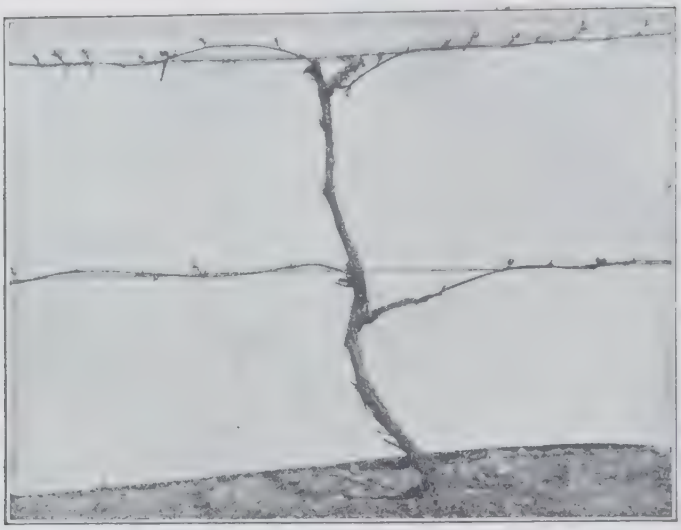
Some merits of this system are: it is adapted to Catawba which tends to make short cane growth, and to Delaware which is a weak grower; certain varieties, such as the two just noted, whose shoots readily assume a vertical position are fashioned well to this system; it is adapted to thorough spraying when properly summer tied; and, short posts may be used.

Some objections are: summer tying of shoots is required, probably even more so than for other systems; some fruit is produced near the ground and becomes dirty; yield is frequently comparatively low; clusters of Concord often are undersized; the canes often are blown down in summer; and, since the fruit is borne close to the lower wire, picking is a "back-breaking" job.

FAN SYSTEM. This system involves training the vine to the shape of a fan. In the true Fan system, there is practically no trunk, and the vine growth is annually renewed to just above the ground. It is commonly



Fan system of training, after pruning.



Single-trunk four-cane Kniffin system of training, after pruning.

modified into many forms, and the leading procedure is to carry the trunk up to or above the height of the first wire. The canes are cut back to 6–10 buds and tied in an upright manner to the top wire; two or three wires are used.

Some merits of the modified Fan system are that comparatively short posts suffice, it is well adapted to regulating the number of canes according to the vigor of the vine, and it is suited to Catawba and Delaware. The objections are much the same as for the High Renewal system. There is often so little uniformity in the training that with many vines it is difficult to distinguish between the so-called Fan system and a poorly developed Chautauqua system.

Systems with Drooping Shoots

SINGLE-TRUNK, FOUR-CANE KNIFFIN SYSTEM. It is used almost exclusively in Michigan, Arkansas, and Niagara County, N. Y., and is also used extensively in most districts where Concord is grown.

A permanent trunk is trained to the upper of two wires. Four canes, two to the right and left of the trunk, are selected and tied to wires. The lower wire is 3–3½ feet aboveground, and the upper 2–3 feet higher at a height of at least five feet.

A trunk is carried to the lower and upper wires at the first opportunity and tied. Often a year more is required to reach the top wire than the lower

one. In this event a cane from just below the lower wire is extended to the top wire. Canes with 8–10 buds are extended from each side of the trunk along the wires. As growth is most vigorous at the top wire, several more buds may be left on the upper than on the lower canes. The canes should arise each year close to the trunk; otherwise, crowding with adjacent vines eventually occurs.

Some merits of this system are: summer tying of shoots is unnecessary and thus much labor and expense are saved; cultivation can be done with no injury to the shoots; the drooping foliage prevents sunscalding of the fruit; only two wires are needed; vigorous varieties with a natural drooping habit, such as Concord, Worden, and Niagara, are well adapted to this system; though not the simplest or easiest of systems to train, yet it is fairly so; air circulation in the vines is good; the foliage and developing clusters are well disposed for spraying; the fruit is fairly easily harvested; the canes are permanent for the year once tied in the spring; and, most of our information on best cane diameter, length of internode, length of cane, and so forth, is based on studies with vines trained to this system.

Some objections are: tall posts are required (this may be a good investment); heavier wire is needed than for some other systems; it is not particularly well suited to varieties or conditions where growth is slow or to varieties with upright growing shoots; it is not well suited to increase in number of canes when the growth warrants it, though the canes may be pruned longer to compensate; attempts to use the system when the posts are not tall enough give unsatisfactory results; and, when the canes are not pruned or tied in the best way, some bunches may become tangled with the wires and canes, thus decreasing the ease of harvesting.

Umbrella Kniffin. This system finds favor in northern Pennsylvania, particularly at North East. A trunk is carried to, or near to, the top wire, from the head of which canes are carried obliquely, at an angle of about 45°, to the lower wire. Usually two canes, but occasionally four, and sometimes three (two on one side of the trunk and one on the other), are used. The formation of a Y-terminal of the trunk slightly below the upper wire permits the canes to be more readily bent without breakage. Also, the canes may be carried over the top wire and then downward. When three wires are used, the central wire is erected a little nearer to the lower wire than to the upper wire.

Some merits of this system are: the crop is superior in size of bunch and

Renewing a crooked old vine to the six-cane Kniffin system. The new portion is two years old. The old trunk will be cut away completely. (Courtesy, Hort. Exp. Sta., Vineland, Ontario.)

berry, compactness of bunch, and maturity; summer tying is unnecessary; the vine is quickly and easily pruned; good air circulation is possible; the canes are permanent for the year once tied in the spring; tying is easily and quickly done; it is adapted to table-grape purposes; the grapes are easily sprayed and harvested; and, it requires a minimum of time and cost.

Some objections are: leaf surface is reduced to a minimum, and so healthy growth is particularly necessary; yield is slightly less than with other systems; canes are often left longer than the optimum of 8 to 12 buds; and, breakage of one cane, as in tying, materially reduces the crop.

Two-trunk Kniffin. This system requires two trunks. The trellis is the same as for the Single-trunk Kniffin. One trunk reaches to the lower wire and the other to the top wire. A cane is tied to the right and left along each wire. The chief merit is theoretical; namely, that a trunk will supply nourishment for two canes better than for four. However, damage to the trunks in cultivation occurs more often than with other systems; and, all factors considered, the system is of questionable value for commercial vineyards.

SIX-CANE KNIFFIN SYSTEM. A cane is trained to the right and left of the trunk along three wires. A merit of this system is that it spreads the growth over a larger area, thus making cultural operations such as pruning, spraying, and harvesting somewhat easier. Then there is also the advantage that in unfavorable years more of the vine is spread out to the wind and sunshine, thus lessening disease and hastening maturity. In yield there is a slight difference in favor of three wires, but not enough, except perhaps on very rich soil, to condemn the two-wire system on this account.

Some objections are: more pruning cuts and more ties are needed than with other Kniffin systems; three wires are needed; the crop and growth on the lowest wire are not always satisfactory; tall posts are required; and it is not suited to varieties that fruit best on comparatively long canes.

MUNSON SYSTEM. In this system, which was adapted for the Southwest, two wires pass over the ends of 2 × 4 wood cross-pieces about two feet long, set at right angles to the row on posts 4-4½ feet high. A third or central wire, about six inches lower than the others, is passed through posts or fastened to them. A trunk is brought from the ground, is at first supported by a stake and is later tied to the lower or central wire where a head with short arms is established. A cane is tied to the right and one to the left of the trunk on the central wire. The purpose of the two upper outside wires is to support the growing shoots, which naturally develop from the canes and gradually droop toward the ground.

Some merits are: the grapes are protected from the sun; it is decorative and thus adapted to country estates, arbors, and in the home garden; the pendant clusters which are plainly to be seen appeal to the grape fancier; a person can pass from row to row under the vines; summer tying is unnecessary; air circulation is good; the fruit and foliage are out of the way of tools used in cultivation; the fruit is not near the ground, and thus dirty fruit is avoided; and, the canes are permanent for the year once tied in the spring.

Some objections are: the trellis is complicated and expensive to construct; tying and harvesting are rather difficult; spraying must be done with a trailing hose; and, the cross-arms interfere with cultivation.

HUDSON RIVER UMBRELLA SYSTEM. This system is used to some extent in the Hudson River Valley, and, though it bears the name Umbrella, it is not a true Umbrella. The trellis is similar to that for the Kniffin, but the wires are closer together. The upper wire is placed at the height of the

Kniffin, but the lower wire is 20 to 24 inches below it. The trunk is carried to the upper wire as in the Kniffin, but from this point it assumes a form similar to a reversal of the Chautauqua system. The shoots droop and attach themselves to the lower wire.

Training Grapes on Home Arbors

Each case where vines are trained to an arbor around the home is, more or less, "a case unto itself." Frequently the shade provided by the vine is as desirable as the fruit; this complicates the pruning problem. The height of the arbor may be six feet or more. One trunk for each vine suffices, but several trunks may be used. The basic principles which are useful in pruning in vineyards (and which are discussed later) are also useful in pruning vines trained on arbors. The inexperienced pruner seldom removes enough wood or else removes the most productive wood. The number of buds on arbors can be increased beyond that in vineyards, but with too many buds the size and quality of the fruit and probably also the vigor are sacrificed.

Yield of Grapes from Different Systems

In New York,[220] Table 6, vines trained to the single-trunk, four-cane Kniffin gave the highest yield for an eight-year period. The High Renewal was the lowest yielding. In Missouri,[208] Table 7, the High Renewal ranked low in yield. The Y-trunk Kniffin ranked highest in yield of the other three systems compared, but the differences were slight. A study

Table 6

FRUIT WEIGHTS IN TONS PER ACRE FROM DIFFERENT GRAPE TRAINING SYSTEMS. NEW YORK[220]

System	*1911*	*1912*	*1913*	*1914*	*1915*	*1916*	*1917*	*1918*	*8-yr. av.*
Munson	3.50	4.00	2.20	4.40	5.40	2.99	4.50	1.59	3.57
Single-trunk Kniffin	5.44	5.20	2.21	5.16	4.62	3.23	3.57	1.89	3.91
Chautauqua	5.20	5.13	1.88	5.06	4.52	2.39	3.62	1.75	3.69
Umbrella Kniffin	4.38	4.52	2.22	4.35	4.42	2.60	3.91	1.76	3.52
High Renewal	3.80	2.65	2.01	4.68	2.97	1.55	2.88	1.42	2.68
Two-trunk Kniffin	4.59	4.59	1.46	4.99	3.77	2.55	2.80	2.02	3.34
Horizontal Arm changed to	3.11	2.94	..	..	..	..	..	..	3.02
Hudson River Umbrella	..	..	..	3.93	5.37	2.96	3.74	2.75	3.75

Table 7

AVERAGE YIELD IN TONS PER ACRE OF FOUR GRAPE TRAINING SYSTEMS. MISSOURI[208]

System	*Moore 4-yr. av.*	*Concord 5-yr. av.*	*Hartford 5-yr. av.*	*Herbert 5-yr. av.*	*Champion 5-yr. av.*	*Average Yield of Five Varieties*
Single-trunk Kniffin	1.682	3.030	4.437	2.890	3.541	3.116
Y-trunk Kniffin	1.928	2.984	4.171	3.055	3.607	3.127
Recurve	1.874	3.206	3.942	2.843	3.840	3.068
High Renewal	1.751	2.455	3.267	2.110	2.729	2.462

over a three-year period in Illinois,[110] with full-bearing vines, showed that Worden and Moore Early can be trained to any one of the three types of trunk (Single, Y, and Double) without much variations in yield.

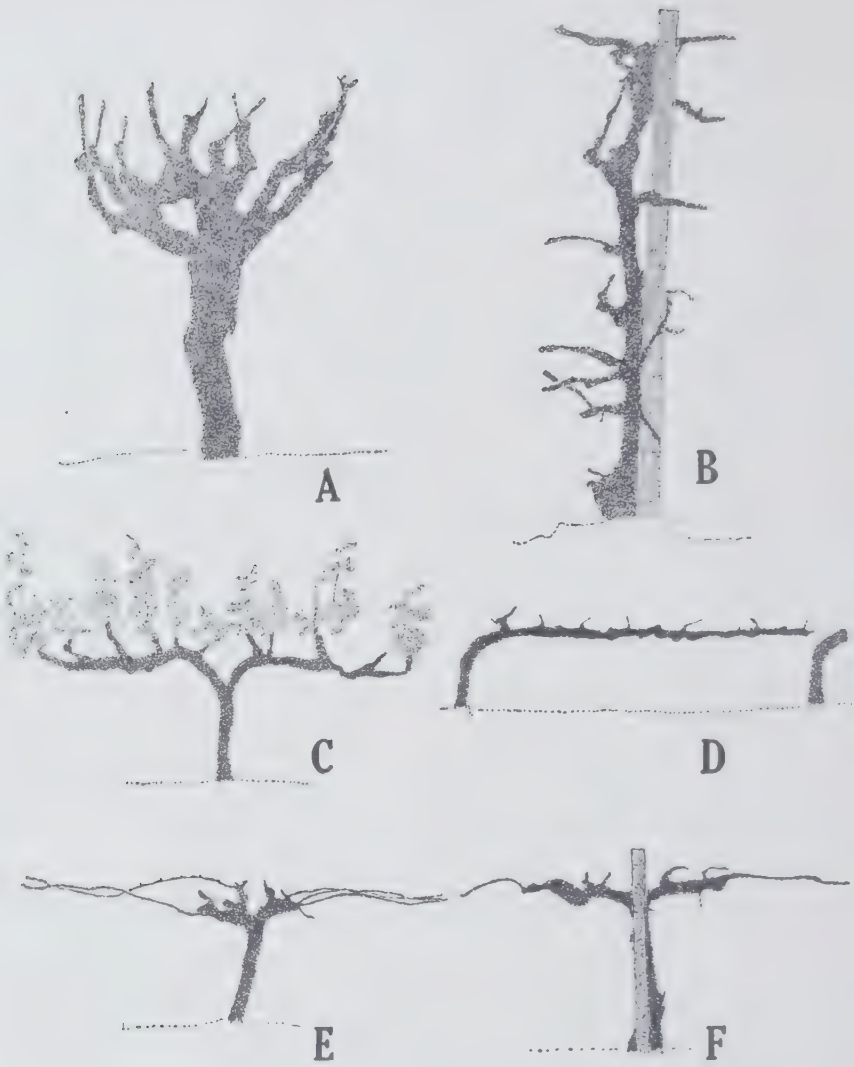
The system of training affects differences in yield to a lesser extent than do many other cultural factors. Therefore, the choice of system usually depends on factors other than differences in yield.

TRAINING VINIFERA-TYPE GRAPES

The systems of pruning may be grouped[524] into three general types for which *head pruning*, *cordon pruning*, and *cane pruning* are convenient names. The first two of these general types and their subtypes, on which the retained annual growth is usually reduced to spurs, are distinguished by the form that is given to the more or less permanent parts of the vine. The third general type and its subtypes take their name from the bearing unit — the fruit cane—and the position of the bearing units on the supports.

HEAD PRUNING OF VINIFERA GRAPES

The mature vine consists of a vertical stem or trunk bearing at its summit a ring of arms or short branches ascending in the form of a vase or hollow inverted cone. At the end of these arms, at each winter pruning, are left spurs consisting of the basal portions of canes which are the matured shoots that grew during the previous summer. These spurs produce shoots which serve the dual purpose of bearing the next crop of fruit and supplying wood for next year's spurs. Thus, this system consists of head training and spur pruning. The point or region at which the trunk divides into or bears the arms is called the "head."



(A) Head (spur) pruned vine. (B) Vertical cordon-pruned vine. (C) Horizontal bilateral cordon-pruned vine. (D) Horizontal unilateral cordon-pruned vine. (E) Cane-pruned vine. (F) Combination of cordon pruning and semi-cane pruned vine.

This type of pruning is often spoken of as "vase" or "goblet" form. The vase-formed arrangement of the arms, though usual, is not universal nor essential, hence the term "head pruning" is preferable. In regions of very high temperatures and low relative humidity the head of the vine may be sunburned if the vase arrangement of the arms permits the sun to shine directly upon the base of the arms. Under such conditions sufficient

growth should be maintained directly above the head to shade this part of the vine.

Pruning Mature Head-pruned Vines. With a mature head-pruned vine enough spurs are left to obtain a full crop of high quality and still maintain the vigor and form of the vine. The number of buds left is in proportion to the capacity of the vine, and is distributed on the spurs in proportion to the size of canes which were cut back to form the spurs. The spurs are so distributed that the form of the vine is maintained or improved and the fruit is uniformly exposed.

The number of buds or spurs to leave on a mature vine is easily estimated by roughly counting those that were left the previous year and by observing the size of the canes. A vine that produced a good crop and canes of normal size is pruned so as to leave the same number of buds and spurs as were left the year before. If the canes are abnormally large for the variety, and so were very vigorous the previous summer, more buds are left in order to use this capacity in the production of fruit. More buds may be left by either increasing the length of the spurs or their number. The method selected to increase the number of buds should be the one which best retains the desired form of vine and which will also distribute the fruit uniformly. But, if the canes appear weak, i.e., small size for the variety, fewer buds are left. To reduce the number of buds the number of spurs retained is reduced or the spurs are cut shorter. In every case the spurs retained from large or vigorous canes should carry more buds than those retained from small or weak canes.

Advantages. The advantages of head pruning are simplicity of form, ease of training, and cheapness. The headed vine is the easiest type to establish, largely because of its relatively short trunk and the small amount of permanent wood compared with that of the cordon type. The fact that the trunk is upright over its entire length also simplifies the training.

Headed vines are usually relatively small, hence the cost of supports is comparatively low. Stakes are necessary during the development period, but the trunks or stems become sufficiently rigid to be self-supporting after 5–8 years. This type of support permits cross-cultivation when the vines are planted at about the same distance in both directions.

Disadvantages. When the crop is controlled entirely by pruning, as is the usual practice with most head-pruned varieties, the pruning must be severe in order to avoid overbearing. With this type of pruning the

vines remain relatively small and capacity for both growth and production is depressed.

The need of pruning to relatively short spurs not only reduces the capacity of the vine, but also tends to keep the head too compact. The fruit may be of inferior quality owing to its unequal exposure to light and air. As the vines become old and the arms longer, this defect is less serious. Long spur pruning with some form of thinning to regulate the crop helps to overcome the tendency to crowd the fruit and lessens the depressing effect of the pruning.

In some varieties, notably Muscat of Alexandria, the fruit is poor as a result of coulure (shelling) and the setting of shot berries. There is a definite relation between these troubles and the restriction of leaf development early in the season with this type of pruning. With still other varieties the crops are small and irregular with head pruning because the buds toward the basal end of the canes are not always fruitful. Slight variation in the fruitfulness of the buds of a single variety may occur from year to year which may in some cases account for irregular bearing. Long spur pruning with some form of thinning to regulate the crop in the years when more clusters develop than the vine can bring to full maturity may overcome this situation and appreciably increase the average yield over a period of years. If the spurs must be left very long, however, it is difficult to maintain the form of the vine.

Cordon Pruning of Vinifera Grapes

Cordon pruning is distinguished from other systems by the much elongated trunk which bears arms over most of its length. Instead of the usual 1–3 feet, it is extended to 5–10 feet or more. In practice three types of this system are used, namely, the bilateral and unilateral horizontal cordons and the vertical cordon. The trunk of the bilateral cordon rises to 15–30 inches or more where it is divided into two parts, each of which continues through a quarter circle to the desired height and then extends horizontally in opposite directions to the next vine. In the unilateral horizontal cordon the shape of the trunk is similar to the bilateral, but it extends only in one direction and its end overlaps the bend of the next vine. The trunk of the vertical cordon is erect over its entire length.

The vines of the cordon system lack a definite head. The arms are distributed over the trunk at intervals of 8–12 in. In the horizontal cordons

the arms should arise only on the upper side of the horizontal part of the trunk, otherwise the fruit is not exposed uniformly to light and air. The arms of the vertical cordon are distributed around the trunk from its top to within 12–15 inches of the soil. Spurs are left at the end of the arms at each winter pruning. They produce shoots which bear the next crop of fruit and supply wood for the next year's spurs. This system of pruning thus consists of cordon training and spur pruning.

Pruning Mature Cordon-pruned Vines. Since the annual pruning of the cordon vine consists in the leaving of spurs, it is similar to head pruning or any other system of spur pruning. In choosing the wood and estimating the number of buds to leave the pruner proceeds as outlined for head pruning. To maintain the capacity of the individual arms at the same level great care must be used to regulate the length of the spurs left in accordance with the size of the canes of which they are the basal parts. Since the arms of the horizontal cordon are upright the most vigorous growth is usually at the end of the spurs, hence the arms may tend to become too long rapidly unless the wood for the spur is carefully selected and wise use is made of replacement spurs.

Advantages. The length of trunk of cordon-pruned vines distributes the crop well; the clusters do not touch each other. With the horizontal cordons the shoots do not come against or grow through the clusters, and so the clusters are more perfect and more easily picked without injury. This favors uniformity in the development of color, size, and sugar content.

The extension of the trunk in cordon pruning tends to make the buds on the lower part of the canes more fruitful. Some varieties which require very long spurs with head pruning bear fair crops on spurs of normal length when pruned to the cordon system. Pruning cordon vines to spurs reduces the pruning cost to a minimum. In fact the pruning of a well-trained cordon vine is perhaps the simplest of any system.

Disadvantages. The greater length of trunk of the vines of the cordon system makes it the most laborious of the three systems to establish. Also, the workmen must be much more skilled and must use greater care than is necessary with head and cane pruning.

The defects of the vertical cordon possibly offset any and all its advantages. One of these is that the fruit is subject to various degrees of temperature and shading in different parts of the vine, thus the ripening

and coloring are often uneven. A more vital defect is that it cannot be maintained permanently. The arms and shoots at the top of the trunk tend to become more vigorous and the lower arms and shoots, as a result of shading, become weaker each year until finally no growth at all is obtained below. Eventually, most of the vines lose the character of cordons and become simply headed vines with rather long trunks which are weak and short-lived owing to the large wounds where the lower dead arms were removed.

Because the vertical cordons tend to lose their form, the trend with Emperor in the San Joaquin Valley, where this system is widely used, is to develop the vines to a high short bilateral cordon. A one-wire trellis is used to support the cordons. The mature vines are then semi-cane-pruned, leaving long spurs on the cordons and one short cane at the end of each cordon. The length of canes as well as number and length of spurs depends on the capacity of the vine.

The horizontal cordons besides being difficult to establish require trellising which further increases the cost.

Neither of the cordon systems overcomes the tendency of certain varieties to produce straggly clusters or to set shot berries. As in head pruning, these defects are associated with the restricted leaf development early in the season on short spur-pruned vines. Pruning to canes with flower-cluster thinning to regulate the crop reduces these defects. However, cane pruning of cordon vines is impractical under most conditions.

Cane Pruning of Vinifera Grapes

In head and cordon pruning, the spurs have two functions, viz., production of (a) fruit and (b) production of canes for the next year. In cane pruning these functions are separated. The fruit cane bears the fruit and the renewal spur produces canes for the next year. The renewal spur is usually cut back to two buds, one of which is expected to produce a cane which can be cut back the next year to 2–5 feet or 10–15 buds for a new fruit cane and the other to two buds for a new renewal spur. In general, cane pruning of vinifera grapes is patterned after the Kniffin system.

Advantages. A chief advantage of cane pruning is the possibility

of obtaining full crops of fruit on varieties, e.g., Thompson Seedless, of which the buds near the base of the canes are sterile, and with the Riesling varieties, of which the clusters are small.

With the use of thinning to regulate the crop, cane pruning offers two other advantages: it spreads the fruit over a larger area per vine; and, it reduces the tendency of certain varieties, e.g., Muscat of Alexandria, to produce shot berries or straggly clusters. Cane pruning allows the vine to make a greater development early in the season than does any other pruning system. At bloom, other conditions being equal, cane-pruned vines will have produced half to several times more leaves than spur-pruned vines. With the same number of clusters to a vine, the clusters on the cane-pruned vines are better nourished.

Cane pruning is the least severe of the common systems of pruning. Thus, it allows for the greatest development of the vine. Cane-pruned vines will produce much more fruit than will spur-pruned vines and still make an equal amount of growth.

DISADVANTAGES. Cane pruning of any variety that has been producing full crops with spur pruning will result in overbearing and in the production of fruit of poor quality unless it is severely thinned. This is because more buds are retained with this system of pruning and the buds on the canes become more fruitful from the base upward over the length usually retained in cane pruning.

To obtain the benefits of spreading the fruit with its favorable influence on quality it is necessary to establish a trellis and this adds to the cost. Supporting the canes without a trellis tends to mass the clusters too close together.

Cane pruning is the most difficult system. Since the units retained are relatively few in number each must be nearly perfect if regular full crops are to be produced. The selection of one poor cane may mean the loss of one fourth of the crop of the vine. Thus, great care must be taken in selecting the wood to be retained. More care is also required with this system to maintain the form of vine. In spur pruning the units are short, hence the vine cannot get out of shape very fast. With cane-pruned vines, where the units are long, if the pruner is careless in selecting the wood the vine may get out of shape in a few years. It may then be difficult to find suitable fruit wood close to the head of the vine.

Training Muscadine Grapes

Two types of training are employed for muscadine grapes: (a) horizontal or overhead, i.e., the growth is spread as an overhead canopy about seven feet aboveground and supported by posts and a horizontal trellis; and (b) upright or vertical, i.e., the growth is spread over a vertical trellis. For an overhead system the vine is trained to a single trunk from the ground alongside a permanent post. When the vine reaches the top of the post it is pinched off, cut back, or bent over, so as to make it form shoots to grow and spread from this head as the spokes of a horizontal which radiate from the hub. In the upright system, fruiting arms either radiate from a low vine head, like the ribs of a fan, or they are taken off as horizontal arms from a central vertical trunk.

Pruning Grapes for Early Bearing

For many years the custom was to prune the American-type vine to about two buds when planting and in the same manner the next year. The second cutting back seems best only when a weak or fair growth is made. Vigorous vines can be brought to full bearing the third year by forming a trunk (Kniffin system) to the top wire at the end of the first year. Of course, a growth cannot always be found which will reach the top wire a year after planting, but, when it is available, severe pruning delays production without any compensating gain.

Bearing of a full crop by vigorous Concord vines in the third year does not reduce the bearing capacity or vigor in later years.[426,428,429] In Indiana,[244] vines which were pruned more lightly at the start and which were established as a four-cane Kniffin one to two years before those which were more severely headed back continued to be just as productive and at the end of nine years had just as strong trunks and plant vigor as those pruned back to two buds for the first two years.

Plants with the largest amount of top growth have the largest root systems.[428] The diameter and length of the single cane is greater than those of either of the canes on the vines with two canes. But, a larger root system is produced on the newly set vine with two growing shoots than on the vine with one.

Early recommendations for pruning the young vine were to cut it back to two buds and to rub off one shoot in case two developed. The foregoing experiments indicate that lighter pruning in the first few years may be practiced than is recommended in the early treatises on grape culture. Pruning of the young vine should be designed to produce

a straight trunk (Kniffin system) and well-located arms to form the framework of the vine as soon as possible.

Some Factors Related to Pruning Which Influence Fruitfulness

Pruning must be varied to meet the variations in capacity of the vine to bear. There is probably more detailed information available for the pruning of grapes than for any other fruit.

Optimum Number of Buds per Vine

This is influenced by many factors, such as variety, age, and vigor of vine, system of training, and type of cane, including its length, diameter, and so forth. The capacity of a vine to produce a crop during a single year is influenced both by the number of buds left on the vine and their character.

Michigan. The number of buds per foot of Concord cane is larger[354] in the weak than the strong vine. Often a count reveals that more buds had been left on the weak vine than on the stronger one, though the reverse is intended. An occasional check count seems desirable. A vine pruned to the same number of buds for several years produces about the same weight of fruit per year after the first crop. The first year, the crop is nearly proportional to the number of buds retained. Thus, a moderately vigorous vine pruned to 60 buds is nearly twice as productive the first year as a similar vine pruned to 30 buds. The second year, however, a vine pruned to 60 buds does not yield any more, and usually less, than a vine pruned to 30 buds for two years. The average weight of bunches on a 30-bud vine is slightly greater the first year and much greater the second year. Therefore, the quality of the fruit is improved by the more severe pruning. The very strong vine is an exception. If it is severely pruned, the crop is often less per bud and consequently per vine than when it is pruned correctly. The cane growth also becomes so heavy that it is difficult to find good fruiting wood for the next year and the injury extends over a period of years.

The optimum number of buds per Concord cane ranges between eight and 12.[355] The results are better, both in shoot growth and crop yield, when an increase above 48 buds per vine is obtained by an increase in number of canes rather than by an increase on the original four beyond 12 buds. To overcome a tendency in certain vineyards to bien-

nial bearing, heavier pruning in the winter preceding heavy fruiting seems better than lighter pruning in the winter before the off year.

In carefully balancing the number of buds to the vigor of the vine, it is necessary to have a measure of the growth of the vine. The weights given, Table 8, are those of the one- and two-year-old wood removed from the vine at pruning time.[354] This weight gives a fairly good index of the vigor of the vine. The number of buds refers to buds of good productivity, though the basal buds on each cane are counted. It is not advisable to increase this number to any great extent, even though the buds are on small-sized canes, because this will increase the number of growing points and so will reduce the strength of next year's fruiting canes. Two more buds are left for each additional $\frac{1}{4}$ pound of prunings

Tabel 8

OPTIMUM NUMBER OF BUDS PER VINE BASED ON WEIGHT OF PRUNINGS. CONCORD. MICHIGAN[354]

Pounds of Prunings	*Number of Buds per Vine*	*Pounds of Prunings*	*Number of Buds per Vine*
Less than ¼ lb.	16	1¾	36
¼	20	2	38
½	24	2¼	40
¾	28	2½	42
1	30	2¾	44
1¼	32	3	48
1½	34		

in excess of three pounds. The scale may need to be modified for the most vigorous vines which sometimes yield as much as 10 to 11 pounds of prunings and which should have 100 buds or more according to the scale. It is not practical to weigh all the prunings from vines on 40–50 acres. However, a pruner is soon able to estimate the weight of prunings removed from a vine after half a day's training with the actual weighing of the brush. The pruning thereafter will be a little slower than when no estimate is made of the weight and little attention is given to a proper balance between vigor and productiveness. The extra time spent is well repaid at harvest in quality, as well as in yield.

Campbell Early is a special case.[355] Best results are obtained when about two-thirds as many nodes are left as for Concord. As the number of nodes is increased

with Campbell Early, more straggly bunches are produced. These reduce the grade of the crop. The increased number of straggly bunches is because the more nodes left on the vine the weaker is the shoot growth. Underpruning Campbell Early reduces the quality of both the current and next year's crops, because the weak shoots make weak and unproductive canes the next year. Underpruning is likely to result in overproduction, which seems to be more serious to Campbell Early than to Concord.

ONTARIO. A general rule of 28–40 buds per vine is suggested,[349] plus some spurs for fruiting wood renewal when the arms are long. The results are based on maturity of fruit, unimpaired vigor of vine, and continuous yield for a six-year period. Most, if not all, the varieties mentioned (Table 9) give as good yields (and sometimes higher) where the number of buds exceeds by four or more the optimum noted. Date of maturity of the fruit as influenced by size of crop is important in the Niagara district, especially where the vineyards tend to be late in maturing, e.g., vineyards close to the lake. In general, the larger the crop the later is the maturity. Therefore, the grower who habitually suffers from too late maturity should practice more severe pruning. In this case, the optimum number of buds is determined by date of maturity rather than by the quantity of fruit that the vine can support yearly without noticeable impairment of vigor.

Table 9

OPTIMUM NUMBER OF BUDS PER VINE, ONTARIO, CANADA[349]

Variety	*Number of Buds*	*Variety*	*Number of Buds*
Vergennes	28	Herbert	40
Brighton	32	Lindley	40
Concord	36	Niagara	40
Delaware	36	Agawam	44
Diamond	36	Massasoit	44

MISSOURI. The ideal number of buds is between 40 and 60, and nearer 40 than 60.[205] Vines pruned to 40 buds just about maintain their growth, judged by the weight of the prunings; those pruned to 20 buds increase their growth about 22 per cent, or nearly one fourth. Vines pruned to 60, 80 and 100 buds show almost a regularly graduated reduction of growth as indicated by the weight of the prunings. In fact, on

many lightly pruned vines, it is impossible to find enough wood to [illegible] up the same number of buds again for the next spring.

Table 10

INFLUENCE OF NUMBER OF BUDS PER VINE. MISSOURI[208]

Buds per Vine, no.	*Average Clusters per Vine, no.*	*Average Weight of Clusters, oz.*	*Yield per Vine, lb.–oz.*	*Yield per Acre, tons*	*Weight of Prunings per Acre, lb.*	
					1926	*1927*
20	69	4.4	19–4	5.236	952	1162
40	87	4.9	27–2	7.378	1054	1105
60	148	3.8	35–4	9.588	1156	986
80	178	3.1	34–8	9.384	918	748
100	198	2.0	33–10	9.146	884	612

ILLINOIS. Vines pruned to 25–55 buds per year increase gradually in yield as the number of buds is increased.[110] The rate of increase is much slower after the number has reached 45 than before. Also, as number of buds and yield per vine increases, the weight of cluster decreases, and above 50 the decrease is more rapid. Vines with more than 55 buds[118] yield higher but the bunches and berries are smaller. With very poor producers the number of buds retained is less important than on more productive vines. The total shoot length[125] is little affected by the severity of the previous winter's pruning, but the vigor of individual shoots is increased proportionally. Increasing vigor of weak shoots is seen by increased length, and of very vigorous shoots by the growth of laterals. Total yield is greatly influenced by the severity of pruning which limits the possible number of fruit clusters. When fewer buds are retained and the number of potential shoots is reduced, the number of clusters resulting is automatically lessened. The yield of individual shoots from the buds retained is not seriously changed. The ability of a shoot to yield is largely determined in the bud the previous year; whereas shoot vigor is markedly affected by the number of buds left. The growth of last year's shoot may be used as an index to balance vigor and yield while pruning. Concord vines pruned to 56–65 nodes bear shoots that are moderately vigorous with little lateral growth. Such vines bring large bunches to full maturity each year and mature enough medium-size, well-placed shoots for a good choice of fruiting canes when pruning.

In interpreting these results the rich, deep, local soil should be kept in mind.

NEW YORK. The performance of the Fredonia variety is variable. Six 29-vine rows were trained[399] to the Chautauqua, Umbrella, four-cane Kniffin, and six-cane Kniffin systems, respectively. Two of the six rows were pruned severely, two moderately, and two lightly. Thus there were four training systems with three levels of pruning severity. Where only a small amount of fruiting wood (28 buds for vines with two pounds of prunings) was used, the yield was lowest ($2\frac{1}{2}$ tons per acre). Where a moderate amount of wood (38 buds for vines with two pounds of prunings) was used, the yield was increased by almost a ton to the acre. Using the longest pruning (48 buds to a vine producing two pounds of prunings), the acre yield was increased by another ton. For the Kniffin training systems, cluster size was not affected by severity of pruning, but with the Chautauqua system it was increased by the longer pruning. Thus, severe or short pruning of vigorous Fredonia vines reduces the yield.

FRUITFULNESS PER NODE OR BUD

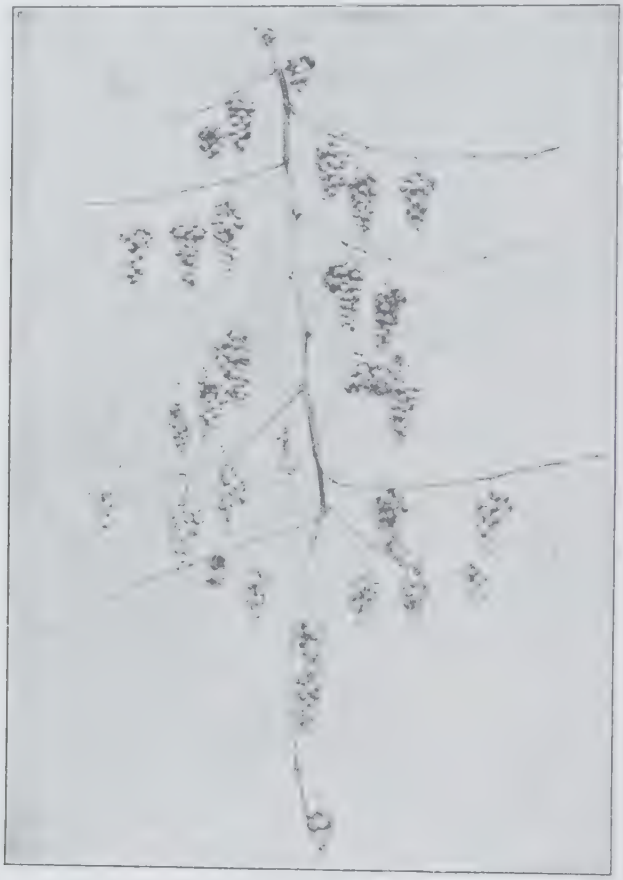
That Concord produces few fruits from the basal nodes of the cane was shown first in Tennessee[281] and later in many other areas. This matter is directly related to comparatively low yields from the "spur" method of training.

The small buds at the bases of canes and on old wood normally remain dormant, but when forced into growth some of them produce fruiting shoots. To determine the fruiting capacity of these buds, vines were pruned in Missouri[400] to leave two-year wood (the previous year's fruiting canes) instead of the canes as fruit wood. All canes were cut back of the first node, without injuring the basal buds. About the same amount of wood was left as when the vines were normally pruned to canes in the Kniffin system. Three groups were made: (a) Missouri Riesling, Etta, Elvira, and Wyoming, which were highly productive, the yield being almost and at times as great as that produced by vines pruned to canes, (b) Moore Early, Concord, and Worden, which were comparatively unproductive; and (c) Diamond, Niagara, and Catawba, which were intermediate and with which the amount of fruit produced from latent buds varied from year to year. Most of the fruit was produced by the buds at the bases of the canes. Rarely did shoots coming directly from very old wood bear fruit. The clusters produced from latent buds were always smaller than those borne by shoots from node buds. Their average weight was one half to three fourths that of cane-produced clusters.

The median portion of the Concord cane is a region of relatively

high productivity. The most productive buds in Michigan[204] are between the fourth and ninth nodes, Table 11.

In Missouri,[205] from 100 canes selected in the order they occurred on the vines, and which ranged from 8–12 buds in length, the high-



Fruiting habit (Catawba variety). Note that the best size and number of bunches are on the shoots arising from nodes on the medium portion of the cane. Consider the probable reduction in yield if this cane (which extends from the top of the illustration) had been shortened severely.

producing node on 11 canes was bud No. 5, on 11 it was No. 6, on 12 it was No. 7, on 14 canes it was No. 8, on 14 it was No. 9, on 12 it was No. 10, on three it was No. 11, and on four it was No. 12.

The regions of maximum production in another study in Missouri[206] are as follows: Missouri Riesling, nodes 7–8; Elvira, 5–6; Wyoming,

7–8; Concord, 7–8; Moore Early, 5–6; Niagara, 7–8; Diamond, 7–8. Worden, Catawba, and Etta, did not show any region of maximum

Table 11

AVERAGE YIELD OF FRUIT PER NODE ON CANES, CONCORD. WEIGHT IN OUNCES. MICHIGAN[355]

Number of Node	*Heavy Loam*			*Medium Loam*			*Light Sand,*
	1921	*1922*	*1923*	*1921*	*1922*	*1923*	*1922*
1	1.5	1.2	0.7	1.9	1.2	0.6	0.5
2	2.4	3.9	2.2	2.4	3.2	2.5	1.8
3	3.3	4.0	2.9	3.1	5.2	3.3	3.4
4	**3.9**	7.5	4.9	**3.7**	7.4	4.6	4.4
5	3.6	8.0	5.9	3.0	7.9	5.3	5.1
6	3.7	8.4	6.1	2.8	7.9	5.4	5.7
7	3.1	**9.1**	**6.2**	2.6	8.0	6.5	6.2
8	3.1	9.0	5.9	2.8	9.2	**6.6**	6.4
9	2.3	8.5	5.9	1.9	**9.3**	5.7	**6.9**
10	1.4	8.7	6.0	2.2	8.5	4.6	5.8
11	1.1	7.8	4.8	0.2	9.3	3.3	5.9
12	1.6	7.0	5.8	..	8.6	3.7	5.0
13	0.9	9.5	4.7	..	7.3	2.2	5.2
14	4.7	4.1	2.6	..	7.2	1.7	4.7
15	..	4.0	1.5	..	..	..	3.2
16	..	..	3.0	..	..	..	5.7
17	..	..	4.0	..	..	..	3.4
18	..	..	4.0	..	..	..	6.0
19	..	..	2.0	..	..	..	6.0
20	..	..	2.0	..	..	..	4.0

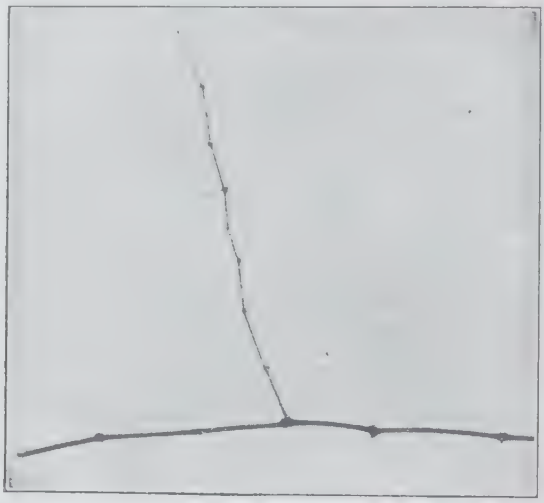
production with the range of 10-node canes, the highest yield being found at nodes nine and 10.

The basal nodes of Campbell Early, as well as Concord, are relatively unproductive.[356] The point of maximum productivity tends to be farther from the base of Campbell Early canes than of Concord. The heaviest bunches, the most bunches per node, the smallest percentage of unproductive nodes, the largest percentage of nodes with multiple shoots, the most productive shoots, and the highest yield occur in the same general region of the cane. The canes should be left long enough to retain this productive region after pruning. In Campbell Early, the number of bunches is influenced more by the percentage of nodes with or without productive shoots than by any other factor. The average weight of bunches is influenced more by the amount of growth made the previous year and by the amount of fruit produced then. Yield is closely associated with vigor of shoot growth. Where

vigorous shoot growth occurs, there is a decreased percentage of unproductive nodes and an increased percentage of nodes producing more than one shoot. The average nodal production of bunches is thus increased by the presence of more shoots on the nodes.

Cane Diameter

Vines which are poor producers are often so because canes of unsuitable diameter are left for fruiting; for example, if 35–40 buds are left as a total for Concord, on canes which are all very large or "bull"



This horizontal cane is a "bull cane." Rather than leaving it for fruiting, if the choice of canes is limited, it is preferable to remove the part beyond the base of the more fruitful lateral. Later, the lateral is trained in the desired fashion on the wire.

canes, poor production can be expected. Not only are such large canes poor producers, but spindly ones also are undesirable.

Frequently, bull canes produce branches at some of the joints. If it is necessary to use large canes, it is best to cut them off just above such a branch and depend on the buds of the branch for fruit. As a rule, branch development is an undesirable growth condition.

The term "canes of moderate size" is sometimes used to express the most desirable type of cane, but this term is often misleading. The use of such canes in a vineyard of low vigor would mean discarding the best fruiting wood to save smaller canes. In very vigorous vines, too,

selecting canes by this standard is unsatisfactory, for the moderate-sized canes are too large for the highest yield with Concord. In this variety, canes whose diameter between the 5th and 6th nodes is 0.25 and 0.30 inch are the most productive.[855] The least productive canes are those whose diameter is the smallest (0.12 to 0.15 inch). Canes whose

Table 12

FRUITFULNESS OF GRAPE SHOOTS, ILLINOIS.[126] (THE CLUSTERS ARE NUMBERED FROM THE BASE TO THE TIP OF THE SHOOT)

Range in Number of Clusters per Shoot	*Shoots Grouped According to Number of Clusters Borne*	*Average Weight of Clusters According to Location on the Shoot*				*Weight of Fruit per Shoot in Ounces*	*Weight of Fruit per Cluster in Ounces*
		First	*Second*	*Third*	*Fourth*		
0	10	..	..	..	..	0	..
1	79	2.41	..	..	..	2.41	2.41
2	215	4.34	3.20	..	..	7.54	3.77
3	149	5.08	4.44	2.72	..	12.24	4.08
4	5	4.60	5.40	5.00	3.0	18.00	4.50
Total	458	1903.41	1376.56	430.28	283.0		
Average weight of clusters in order borne	..	4.25	3.73	2.79	3.0	8.13	3.82

diameter exceeds 0.30 inch are less fruitful than the intermediate size canes. Thus, canes the size of a lead pencil or slightly larger are best.

The best canes on Campbell Early in Michigan[260] were at least $\frac{3}{8}$ inch diameter. The vigorous canes produced more shoots per node, more vigorous shoots, and yielded larger numbers of larger bunches than did the smaller ones. Of all cane lengths of Campbell Early, the largest canes proved the most productive.

INTERNODAL LENGTH

There is a correlation between internodal length and yield in Concord.[855] Internodal length is more easily judged than is diameter under field conditions. Canes selected for fruiting should be examined for both these characters, rather than one alone.

It is sometimes suggested that fruiting canes with short internodes should be selected, but these are the least productive. Table 14. With measurements between the fifth and sixth nodes, the higher yields occur where the internodal length is 5–7¾ inches. It is not safe to assume that this length is always associated with maximum yield. It does seem certain, however, that canes with shorter internodes, less than five inches, are usually less productive than those with longer internodes, perhaps

Table 13

AVERAGE YIELD OF FRUIT (IN OUNCES PER NODE). CANES MEASURED BETWEEN FIFTH AND SIXTH NODES. MICHIGAN[355]

Cane Diameter, Inches	*Heavy Loam*		*Medium Loam*		*Light Sand, 1922*
	1922	*1923*	*1922*	*1923*	
5/40	1.3	2.0	5.3	0.3	2.7
6/40	3.6	1.7	5.4	1.9	3.7
7/40	5.2	2.3	5.5	2.7	4.3
8/40	6.2	3.7	6.3	3.7	4.1
9/40	6.5	4.6	7.1	4.7	5.0
10/40	**7.4**	5.8	**8.3**	6.4	**5.4**
11/40	6.1	5.7	7.5	7.9	5.1
12/40	6.6	**6.8**	8.0	**8.5**	4.3
13/40	5.6	6.8	8.2	4.5	4.3
14/40	5.6	..	1.5	3.0	3.6
15/40	..	..	7.6	2.8	5.9

up to eight inches. An internodal length may be so great as to be undesirable; and it is more difficult to find room to train extremely long canes on the trellis.

LENGTH OF CANE

On vigorous, unpruned vines several dozen canes usually may be found. Assuming that 40 buds should be retained for the growth and yield of the next year, these 40 buds could be distributed over 20 canes by cutting back each cane so that only two buds are left near the base of each, i.e., the so-called "spur system"; any remaining canes being completely removed, or, 40 buds may be left on only four canes with 10 buds each. A total of 40 buds may also be left in a number of other ways; however, the results will vary.

Table 14

AVERAGE YIELD OF FRUIT. CANES MEASURED BETWEEN FIFTH AND SIXTH NODES. CONCORD. MICHIGAN[355]

Length of Internode in.	*Heavy Loam Vineyard*			*Medium Loam Vineyard*		
	Av. Diam., 40th in.	*Fruit wt. per Node, oz.*	*Fruit wt. per Bunch, oz.*	*Av. Diam., 40th in.*	*Fruit wt. per Node, oz.*	*Fruit wt. per Bunch, oz.*
1–1¾	6.0	1.4	1.8	7.5	3.9	2.1
2–2¾	2.9	2.6	2.0	6.7	2.5	1.9
3–3¾	7.6	3.2	2.2	7.6	3.1	2.1
4–4¾	8.6	4.0	2.5	8.6	5.1	2.7
5–5¾	9.4	5.6	2.8	9.9	5.8	3.0
6–6¾	9.9	4.8	2.7	10.0	5.6	2.8
7–7¾	10.6	5.9	3.0	11.0	8.6	3.2
8–8¾	11.5	4.9	2.9	11.0	3.1	2.0
10	..	..	..	15.0	2.8	1.9

Table 15

INFLUENCE OF ORIGINAL LENGTH OF CANE GROWTH ON THE FRUITING OF CANES. MARYLAND[428]

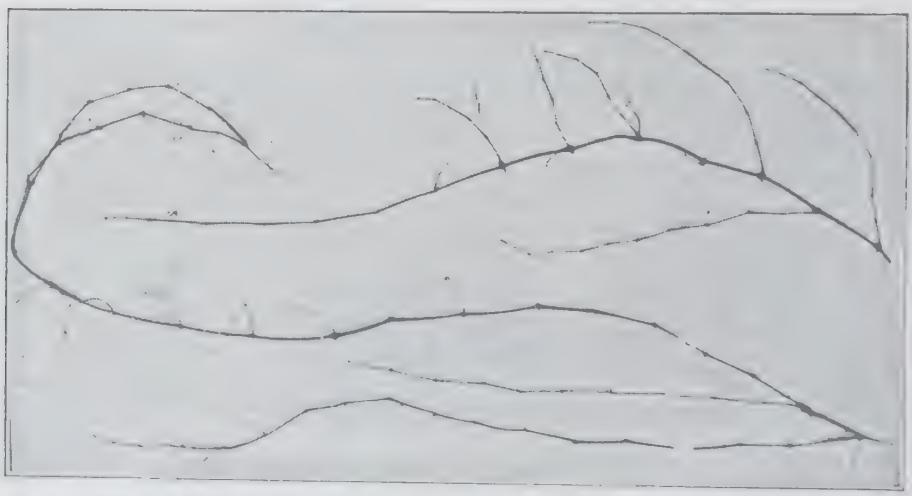
Original Length of Canes in Feet	*2–3*	*3–4*	*4–5*	*5–6*	*6–7*	*7–8*	*8–9*	*9–10*	*10–17*
No. canes averaged	24	47	58	46	45	20	10	10	6
Av. yield per cane in ½ oz	56	82	101	104	124	127	118	113	107
Av. yield per shoot in ½ oz	7.81	9.54	9.93	10.16	11.12	11.95	10.02	10.29	9.41
Av. no. bunches per shoot	1.70	2.04	2.14	2.21	2.34	2.54	2.28	2.41	2.29
Av. wt. of bunch in ½ oz	4.6	4.68	4.64	4.59	4.76	4.59	4.40	4.27	4.13
Av. no. bunches per cane	12.1	17.6	21.7	22.6	26.5	26.9	26.9	26.5	25.8
Percentage of buds not starting	4.5	8.8	10.5	12.0	7.1	10.7	6.4	7.6	11.7
Av. no. buds on unpruned canes	7.9	10.5	14.1	17.6	21.5	24.2	24.6	27.7	35.0
Av. no. buds on pruned canes	7.1	9.5	11.3	11.6	12.0	12.1	12.6	11.9	12.8

Vines pruned to canes yield 40 per cent or so higher than do spur-pruned vines.[819] Spur-pruning too often and too easily develops into a shearing process. Growers who change from spur to cane pruning seldom if ever go back.

With respect to length of cane before pruning, 6–8 foot canes are the most fruitful in Maryland,[428] Table 15. Concord and Brighton canes of 7–9 foot original length are the most productive in New Jersey.[193]

In Missouri,[208] 9–10 foot canes are the most productive of those on the upper arms, with an average of seven pounds 13 ounces per cane. The 7–8 foot canes give the highest yield of the canes on the lower arms, with five pounds five ounces per cane. The yield on both upper and lower arms increases regularly as the length of the cane increases up to the point of maximum production and then decreases regularly as the cane length increases. So long as the total number of buds on the vine is not excessive, the length of an individual cane does not materially affect the yield of the vine, but the yield and size of clusters on the cane is affected.

In Illinois,[115] the most productive cane of Moore Early grows about 5–6 feet long. With Concord, it makes very little lateral growth in an



Fruitfulness of grape canes. (A) Cane with many laterals; the main cane is not highly fruitful; the laterals could be saved for fruiting but these are not the most desirable types. (B) Too highly vegetative; not highly productive. (C) Too weakly vegetative, not highly productive. (D) Productive type. (See discussion on Cane Diameter, p. 98; Internodal Length, p. 99; and Length of Cane, p. 100.)

ordinary season; it may be longer than that of Moore Early, however, up to 10 feet, since Concord is inherently more vigorous.

After pruning, the best length of Concord cane is 8–12 buds.

With Campbell Early in Michigan,[360] canes with 15 nodes are the most productive. The shorter the canes are pruned the greater is the percentage of unproductive nodes. Shoot growth of the same vigor on comparable canes is less productive on shorter than on longer canes. The advantage in yield on the longer canes is less pronounced when canes of small diameter are compared than it is when the canes are more vigorous. If the vines are not strong enough to support four 15-bud canes, it seems better to reduce the number of canes rather than to reduce the number of buds on the individual canes very much. The last five nodes on 20-bud canes yield less than the median portion; and, under the same pruning treatment, 20-bud canes yield less than 15-bud canes.

Yield of Upper and Lower Canes

In the four-cane Kniffin, the practice is often to leave a few more buds on the upper canes. This practice, as well as a number of others, indicates that the upper canes are more productive than the lower canes. In fact, the shoots on upper canes produce larger and more clusters per shoot than do shoots on lower canes.[469]

Relative Fruitfulness on Parts of Different Origin

In pruning with the Kniffin system it is well to leave, besides the four canes, about four two-bud spurs which are wood of the same age as the canes. The role of these spurs is to provide a desirable place of origin for fruiting canes the next year. The aim, furthermore, is to keep new canes originating close to the trunk, instead of having to select canes relatively far out and intermingled with adjacent vines.

Canes that arise from the trunk or from short arms give yields somewhat higher than do similar canes growing from long arms.[355] The difference is not sufficient to warrant the selection of a cane of poor external characteristics merely because of its favorable location on the vine. The difference in yield of buds on canes which grow from different types of older wood is not marked. Best results are obtained from canes that grow from buds on last year's canes. The buds on laterals pruned to spurs are more fruitful than those of the parent cane when it exceeds $\frac{1}{4}$ inch in diameter. The smaller the cane, the less is the yield of the lateral buds in comparison with the buds of the parent cane. Laterals are best retained for fruiting only when the canes are very large and vigor-

ous. In such cases the internodes of the parent cane are very long, and it is convenient to shorten its length by substituting for some of its buds some of those of the laterals.

Tying Grape Vines on the Trellis

Tying the vines on the trellis is a necessary vineyard practice. With certain systems of training, tying soon after the pruning in the dormant season is all that is required. The tendrils from the shoots help to hold the vines on the wires. With certain other systems, summer tying of the shoots is also necessary. Good pruning and training may be ruined by improper tying.

Some purposes of tying are: to assure that the trunk, arms, and canes (and with summer tying, the shoots) are arranged on the trellis in the desired manner; to expose the leaves and fruit properly to air and sunshine; to protect the vines from destructive winds and from injury from implements used in tillage; and to avoid sagging, crooked trunks which interfere with many vineyard practices. When the vines are tied relatively early, tillage may be begun early without mechanical damage to them.

When tying with grape twine it is advisable to give the cord a couple of turns around the wire, knot it, and then tie the cane securely to the wire. This method prevents any slipping of the cord along the wire, and, at the base of the cane, permits of a secure though loose tie, thus allowing for cane expansion. Tying when the canes are frozen should be avoided because they are brittle and break easily. On a cold day, the fingers soon become numb, and the speed and facility of tying are decreased. The wires should be tightened before, rather than after, tying. The winter tying should be completed before growth starts because there is danger of destroying the swelling buds and new growth. Summer tying, when the system needs it, requires that the vines be gone over frequently to take care of the fast developing shoots.

The winter tying of the canes is done firmly with material which is strong enough to withstand considerable strain as the ties are to last for the year, and it is desirable that the canes as well as arms and trunk be held steady. However, avoid girdling of the trunk and main arms. The summer shoots are tied more loosely as they are to hold for a shorter time.

Jute twine is a good material for winter tying. Binder twine is difficult to sever the next year. Willows, fine wire, and the inner bark of the basswood may be used for winter tying. Wire should not be used to secure the trunk and main arms of the vine to the trellis because of the danger of girdling the vines. Wool twine is commonly used for summer tying. Some grape growers grow the required amount of rye for tying. Willows are sometimes used for summer tying also.

The four-cane Kniffin system requires at least four ties, which are tight ties, one near the end of each of the four canes. The trunk may be tied rather tightly to both wires, but with mature vines the lower tie is not always necessary. Besides the ties near the ends of the canes, others are frequently made near the base of each of the four canes, especially if the trunk is not tied to the upper wire. Usually, the ties near the base of the canes are made more loosely to avoid binding or girdling. Sometimes, instead of tying the canes near the base and merely stretching them along the wires, they are twisted around the wire and tied. This twisting, though fastening the canes well, increases the difficulty of removing them the next year. It saves little if any time over tying, and the saving in twine is comparatively small.

The winter tying requires about 8–10 hours of man labor per acre, depending on the system of training. For systems that require summer tying about one hour of man labor is needed per acre.

Girdling

Ringing or girdling of grapes, which consists of the removal of a narrow ring of bark from the fruiting shoot on the trunk side of the bunch, is not practiced commercially with American-type grapes. It is sometimes used by eastern growers who produce grapes for show purposes. It is best done 3–4 weeks after the bloom begins. If done earlier than this, the ringed shoots will be broken off by high winds. The ringed fruit matures earlier, and both berry and bunch are larger. Late ringing has little effect on maturity and size.

Girdling as practiced in California consists of the removal of a complete ring of bark about $\frac{1}{8}$ inch wide, completely encircling the vine part. It may be done on Thompson Seedless on either the trunk or the fruit canes. On young vines with small straight trunks, trunk girdling may be the cheapest. Old vines with thick bark on the trunks are more cheaply

girdled on the fruit canes. If the vines are girdled on the trunks the wound should be covered. A cheesecloth bandage about 1½ inches wide and long enough to go twice around the trunk and tie is convenient and satisfactory. Covering the wounds to lessen drying out causes them to heal more rapidly and more perfectly. Wounds on the trunk must heal over; otherwise, the vine is seriously injured and may die. Black Corinth (Zante) is girdled primarily to increase the set of berries and hence the crop. The purpose with Thompson Seedless is to increase the size of berry.

Combining girdling and berry thinning, increases of 40 to 50 per cent over normal size can be obtained. Girdling, especially without berry thinning, weakens the vine. Black Corinth usually is girdled during or soon after bloom. Thompson Seedless produces the largest berries by thinning the clusters when the berries are about the size of ordinary buckshot—about one fourth grown. The girdling itself is not very expensive. A good worker can girdle 200–500 vines per day.

Thinning Vinifera Grapes

Thinning is the removal of flower clusters before bloom and of clusters or parts of clusters after the fruit has set. Like pruning it consists in the removal of living parts of the vine and it concentrates the activities of the vine into the parts left. In other respects, however, the effect of thinning is opposite to that of pruning: it strengthens the vine by limiting the crop without diminishing the actual or potential leaf area. Thinning offers greater possibilities in improving quality than does pruning.[524] This is because the regulation of crop by thinning is done when the vine is in leaf, and so a better balance of capacity and crop is possible as the character of the fruit can be materially improved by thinning.

Flower-cluster Thinning. If some flower clusters are removed between leafing out and bloom there are more leaves to nourish the clusters retained. With the increase in ratio of leaves to flower clusters the flowers are better supplied with the food materials that are manufactured in the leaves. As a result, the flower parts develop more perfectly, with a consequent better set of berries and an increase in the percentage of normal berries.

The usefulness of flower-cluster thinning in improving quality is limited to varieties with loose or straggly clusters or that set shot berries, or both, with the usual pruning. These difficulties are best overcome when this type of thinning is done soon after all the flower clusters have appeared

so as to obtain the maximum influence of the improved nutrition on the clusters retained. The earlier the thinning, as long as all the clusters are out, the less expensive it is, since fewer clusters are obscured by the leaves.

CLUSTER THINNING. This means the removal of clusters after bloom, i.e., soon after the berries have set. It does not influence the number of berries to a cluster and, since entire clusters are removed, it does not change the character of the clusters retained. Its usefulness in improving quality, therefore, is limited to varieties that set well-filled clusters. This method of thinning results in improved quality primarily through its influence on uniformity in size of cluster, size of berry, and coloring. The greater uniformity results from the removal of oversize, undersize, and misshapen clusters. The early removal of undesirable clusters improves the conditions of nutrition for the clusters retained and so the fruit develops better, especially in size of berry. Early thinning also prevents wasting of energy by the vine in developing clusters which are to be removed. If done skilfully and with discretion not only is the quality of the fruit improved but the crop is not diminished.

BERRY THINNING. This means removing parts of the cluster. It usually consists in cutting off the end of the main stem and several branches of the cluster or in cutting off enough of the main stem as to retain only the desired number of berries.

Berry thinning can improve quality only when the berries are so numerous as to make the clusters too compact to be of high quality or when the cluster parts are so large as to interfere with proper coloring and maturing. Its usefulness in improving quality, therefore, is limited to varieties that set very compact or very large clusters. Berry thinning usually changes the character of the cluster materially. It always reduces its size and may alter its shape.

Berry thinning is done as soon as possible after the drop of berries that normally follows bloom is complete. When it is delayed 8–10 days the gain in berry size is usually about a third less; and when delayed 15–20 days it is two thirds less.

THINNING AMERICAN-TYPE GRAPES

Uneven ripening of bunch grapes is a common drawback, particularly in the more southern areas. It is shown in black varieties by the presence of green, pink, and blue berries in the same cluster at harvest time. When the proportion of green and pink berries is high, the cluster is not market-

able. A few green and pink berries in a cluster lowers the grade and quality, which necessitates hand trimming the cluster if it is to be marketed.

The uneven ripening is associated, in part, with a ratio of fruit to leaf area. Cluster thinning, i.e., removing the small clusters at or near the time of bloom, limits the load of fruit without reducing the leaf surface. In Arkansas,[154] neither cultural practices nor fertilizer affected uneven ripening materially; heavy dormant pruning was accompanied by more even ripening; summer pruning aggravated uneven ripening; and thinning Concord grapes to one cluster per shoot materially increased evenness of ripening. However, thinning of clusters resulted in a heavy reduction in yield, so could not be recommended.

The juice from fruit on blossom-thinned Concord vines contains a higher percentage of total solids than does that from unthinned or slightly thinned long-pruned vines (80-90 nodes instead of the usual 42-50).[155] In Campbell Early[156] the smaller the yield, the higher is the percentage of total solids.

The weight of Concord cluster at harvest is correlated with the length of the shoot just prior to the time of fruit setting.[157] Also, thinning to one cluster per shoot before the berries set results in an increase in growth of the shoot. When a treated shoot is used as a unit for comparison with an untreated shoot on the same vine the individual shoot responds in some degree independently of other shoots on the same vine and of the vine as a unit. A desirable large-leaf area development before bloom may perhaps be promoted by cultural and fertilizer practices which will materially aid in the development of large compact clusters.[158-162] A cluster thinning practice to remove blossom clusters from weaker shoots and to limit the number of clusters per vine by thinning, based on the capacity of the vine, may be a means of increasing the fruit quality, improving the vegetative vigor of the vine and regulating the biennial bearing habit which results from overbearing.

Long pruning and removal of excess blossom clusters results in a slight increase in vigor and larger bunches of better appearance than when the crop is regulated entirely by dormant pruning.[163] There is little difference in the time of ripening when the yield is equal under the two systems of management. But, much more labor is required for pruning and tying. Extra labor is also needed for thinning the blossom clusters while the regular vineyard operations are demanding attention. Under present conditions of marketing, there is no probability of securing more than a moderate premium for the better quality that would be secured by the more laborious method of production.

HARVESTING AND MARKETING GRAPES

Containers

Attention should be given to harvesting equipment some time before the fruit ripens. Containers must be available at picking time and should

be ordered well in advance, and a supply of the necessary baskets and so forth should be obtained as soon as a reasonably accurate estimate of the crop can be made. Some idea of the number of containers necessary may be obtained from the section on *Yield*, but records of previous crops or of those grown by neighbors may serve as a better local guide.

For the American-type grape the chief market type of container is the Climax basket, in two-, four-, and 12-quart sizes. In Canada, the six-quart size is commonly used. Grapes for juice purposes are usually picked and sold in bushel containers which are returned and used again. In the bushel basket, crushing of the berries and leakage often occur. The wooden lug box with outside dimensions of 24" × 12" × 6" is used in large commercial juice areas.

Standard containers have no established legal weight in Canada. The net weights which follow are averages adopted by the Dominion (Canada) Bureau of Statistics:

Blackberries, quart	1¼	pounds	Grapes		
Black currants			Six-quart flat basket	7	pounds
Six-quart flat basket	9	"	Six-quart leno basket	8	"
Quart	1¼	"	11-quart flat basket	13	"
Blueberries			11-quart open basket	14	"
Six-quart flat basket	7	"	Bushel	50	"
11-quart flat basket	15	"	Loganberries, quart	1¼	"
Quart	1¼	"	Raspberries, quart	1¼	"
Gooseberries			Red currants		
Quart	1¼	"	Six-quart flat basket	7	"
Six-quart flat basket	8	"	Quart	1	"
			Strawberries, quart	1¼	"

Stage of Maturity

The period during which grapes may be harvested is relatively long, but they are not at their best unless picked at the right time. The proper stage of ripeness for harvesting is influenced by the use to be made of the

fruit. For jelly making, fruit of a given variety should be picked relatively early. When picked too early, however, yield is decreased, and if too mature the jelly may be unduly dark and contain numerous crystals. Picking for table use is usually started earlier than for juice purposes.

Many grapes are picked too early. This is detrimental to demand for the product. Early marketing of immature, low-quality grapes creates an unfavorable opinion among buyers. There is often much temptation to pick most varieties before they are properly mature. Green or yellow varieties, such as Niagara, are even more deceiving than darker ones, when maturity is judged by color, and they should be allowed to develop full, characteristic flavor before being picked. Grapes reach full size and develop good color some time before they are fully mature.

In a four-year experiment at Vineland, Ont.,[282] by cutting two weeks ahead of proper maturity 11.4 per cent less crop was harvested of Niagara and 9.6 per cent less crop of Concord. That is, had a grower waited until the fruit was mature, for every ton of grapes he cut two weeks early he might have cut 2,228 pounds of Niagara and 2,192 pounds of Concord. In six-quart baskets, this increase amounts to 25 baskets of Niagara and 21 baskets of Concord per acre.

Within reasonable limits, the longer the grapes are left on the vines, the higher is the sugar content. There is no appreciable increase in sugar after grapes are removed from the vine, a fact accounting in large part for low quality in grapes picked too early. These two statements probably need qualification, because it is not always realized that other considerations besides sugar content enter into the matter of quality; for example, a variety may taste sweet not because the sugar content is particularly high but because the acid content is relatively low. Incidentally, the usual simple tests for "sugar" in grapes determine total solids, not just sugars. Quality depends largely on the relation or proportion of acid and sugar (perhaps, also, astringent materials, such as tannin). The greatest part of the total solids of the grape consists of the invert sugars, glucose and fructose. The content of sugar varies with many conditions; it is commonly 15 to 20 per cent in mature grapes.

The chief acids of vinifera grapes are tartaric, malic, tannic, phosphoric, and citric; the first two constitute over 90 per cent of the total. The pH of grapes grown in the leading areas of California is higher than in most grape-growing countries. The range too is very great. Generally

speaking, the pH of a wine is relatively the same as that of the must, except in fortified wines, where it is markedly decreased. Though there is a regular decrease in the tartrates and malates during ripening, the percentage of total titratable acids which are owing to the tartaric acid and potassium acid tartrate increases.[5] In the immature fruit, varieties differ in the percentage of titratable acidity which is due to the tartaric acid plus acid tartrate compared to malic acid plus acid malate; however, as the fruit matures, there is a marked difference in the percentage of total titratable acidity which is due to tartaric acid and potassium acid tartrate. The steady rise in the pH during ripening reflects the change in the ratio of acid salts to free acid. In the green fruit, 50 to 80 per cent of the tartrates are present as free acid whereas at maturity only 10 to 20 per cent are in this form. Varieties differ markedly in free acids, e.g., Ohanez and Tokay possess relatively smaller amounts throughout the season than does Sultanina.

Familiarity with the different varieties aids in determining the proper stage of maturity for picking. A guide to the proper stage of ripeness for picking may be obtained from the following factors: taste, color, aroma, changing of the stems from green to brown, shriveling of the stems, softening in texture of the pulp, thickening of the juice, ease with which the berries separate from their stems, freedom of the seeds from the pulp, and sugar content.

Pickers and Picking

The number of pickers required per acre depends on many factors. Many growers pay the pickers by the hour, and others pay by piece work. In the latter event, pickers make more per hour in high-yielding than in low-yielding vineyards, providing a uniform rate per container is paid.

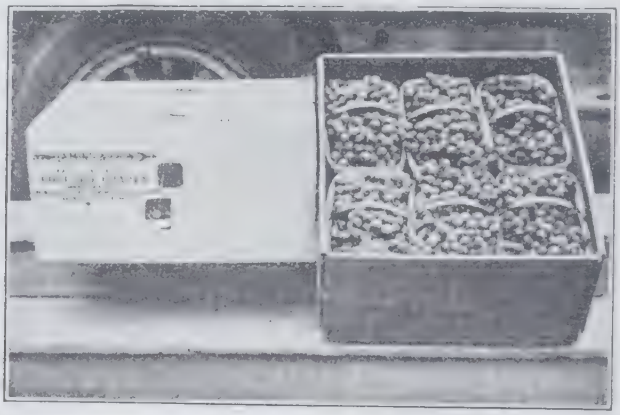
Careful handling of the fruit is necessary with grapes for table use. In commercial vineyards, grape shears or clippers are used to remove the clusters from the vines. The clusters should be carefully placed in the baskets so that the skins of the individual berries do not become broken. The baskets should be well filled (see *Packing*). Though it is desirable that all small, green, cracked, or damaged berries be removed, prevailing prices have not favored the painstaking effort required to remove carefully the inferior berries, which would permit harvesting at one picking.

Grapes for juice purposes are commonly picked directly into the bushel size containers in which the fruit is hauled to the factory or "plant."

Grapes should not be picked when wet. Damp berries decay sooner than do those picked dry. Grape juice manufacturers may hesitate or refuse to accept grapes picked during very warm weather. Baskets of grapes should not be left in the sun any longer than necessary.

Packing American-type Grapes

When eastern grapes are packed the work usually is done in the vineyard. A good type of bench for the purpose accommodates four



One of the newer methods of marketing table grapes consists of the packing of small baskets of fruit in a paperboard container.

baskets in a sloping position. Grading is practicable only when the vineyard run is of good quality and the grapes are plentiful.

To start the pack correctly the lower end of the basket is filled. The package is then filled carefully and snugly to a height of about one inch above the top of the basket. The top of the grapes should be level. All stems should be concealed, and openings between the large bunches should be filled with smaller bunches. A full pack may thus be secured without danger of crushing the berries. The lids should not be put on until the stems wilt and the bunches settle. Finally, the packs are inspected, slack packages are filled, and the lids are adjusted.

Every effort should be made to avoid the need of repacking, for each time the bunches are handled there is danger of bruising and cracking the berries and of destroying the characteristic attractive bloom. Crushing will result if the bunches project too far above the top. If grapes are

crushed in hot weather, mold may develop within a few hours. It is important to place the fruit in a cool place as soon as possible after packing.

Muscadine Grapes. These have the toughest skin and are the most resistant to handling injury of any grapes. The usual practice for juice purposes is to jar them from the vines onto canvas or burlap sheets spread or carried under the vines. The leaves, twigs, and so forth, accumulated with the fruit are separated from it by hand picking and rolling the fruit back and forth on the cloths, or by running the fruit through a fanning mill or other blowing apparatus.

When fruit must remain in good condition for several days after harvest, e.g., for table use or shipping, hand picking is essential. The varieties that do not shatter from the stem readily are best for shipping. Such grapes should be carefully and attractively packed. The ordinary strawberry crate and the two-quart and four-quart grape baskets are the containers generally used for muscadine grapes.

Storage of Grapes

The fruit should be sound, free from mildews, rots, molds, and other disease and insect damage, carefully handled, and picked on cool days or during the cooler parts of the day. Crates made from orange-box material and two feet long, one foot wide, and 6 inches deep are useful. The sides and bottoms are spaced so that air circulates freely through the crate. The freshly picked fruit is carefully laid in the crate, to a depth of not over four inches. Some time before picking, the crates are sprayed with a solution of two pounds of copper sulfate dissolved in 50 gallons of water. The crates are placed in a single tier on shelves made of narrow strips of wood so that air circulates well. Before storing grapes in the special storage room or cellar, precooling should be provided by opening the windows or doors during the night and closing before the hot period of the next day. During warmer days of late fall and early winter the air in the storage room should be changed by opening windows to the outside.

In commercial cold storage of vinifera grapes, every precaution should be taken to prevent even a trace of freezing in the berries. Not only the maximum point of ice formation in the fruit but also the fluctuations of air temperature within the average storage room must be considered. A minimum storage temperature of 28.5° to 29° F. is suitable for grapes in a well-equipped storage warehouse.[58]

For Malaga and other succulent grapes, the air temperature should not fall below 30° F.

In Illinois,[111] in storage at 35° to 40° F., Brighton kept 153 days and Delaware 141 days. Other good keepers were Barry, Diamond, Herbert, Caco, Agawam, and Vergennes. As a rule, red grapes keep better than black or white varieties.

Commercial Grape Juice

The wholesale annual value of grape juice made commercially in the United States exceeds five million dollars. The largest center of manufacture is at Westfield, N. Y. Grape juice plants are located in nearly all regions where the Concord is grown. Most grape juice offered for sale is blue and is made from Concord.

In the commercial preparation of grape juice, the process is usually as follows: the grapes are stemmed, crushed, heated in kettles to about 55° C. (130° F.) for about 10 minutes, the juice expressed by hydraulic pressure, heated to about 76° C. (170° F.), filled into carboys while hot, and the carboys stoppered and stored for several weeks or months for the crystallization of the potassium bitartrate. The juice is drawn off by syphoning, leaving behind a sediment and a very turbid stratum of grape juice, transferred to small bottles, and pasteurized at about 76° C. It is then ready for market.

Instead of using small bottles, some processors market unfermented grape juice in small barrels. The juice is cooled and "sulfured" before it is marketed.

Most early varieties are only fair for juice purposes. Niagara juice appeals little in either color or taste. Both Catawba and Delaware make excellent juice, though the addition of a darker sort improves the color. Clinton, Norton, Bacchus, and Clevener are valuable sorts for blending with almost any variety. When about 10 per cent by volume of juice from Clinton is blended with that of Concord, a highly colored tasty product results and one that will not fade.[227] The Clinton also adds a tartness that is most pleasing to many palates.

SPRAYING GRAPES FOR CONTROL OF DISEASES AND INSECTS

Facts About Spraying Grapes

The origin of Bordeaux mixture, an outstanding spray solution, traces back to its use on grapes in France in 1882. The first applications were not made for disease control but to cover the vines with material so that fear of poisoning would prevent stealing of the grapes. Even

though applied crudely by brooms or whisks of heath, it provided a notable control for downy mildew.

It is impossible to construct a spray schedule for grapes that will have general application. The disease and insect problems of vineyards in different communities, and even in the same community, are frequently quite variable; for example, grape mildew, though a serious disease on the Lake Erie Islands and at the west end of Lake Erie, is rarely a serious problem in the commercial grape belt east of Cleveland. Rose chafer usually is troublesome only in vineyards with sandy soil. Nearly all grape insects are quite localized in their distribution even within the same vineyard. In many commercial vineyards of recent planting and in some home plantings, excellent grapes are being grown without any sprays. In other plantings one or, at the most, two applications of spray will control the trouble present.

Each grower should study his conditions and apply only such sprays as are found necessary. It cannot be too strongly emphasized that in the spray program the early sprays are most important. Infection of leaves and canes must be prevented if clean fruit is to be produced. Little can be accomplished if spraying is postponed until the fruit begins to rot. Thoroughness is very essential. In the after-bloom sprays, 125–150 gallons of spray material per acre are necessary in the average vineyard.

In some regions, particularly Michigan, tanglefoot (a sticky substance like mucilage) is applied to the trunk a few inches from the ground to prevent climbing cutworms from eating the swelling buds. About a pound of tanglefoot is used per acre.

During most years arsenate of lead cannot safely be applied to grapes after the first week of July, because of the spray residue that will be carried by the harvested fruit.

The Rogers' varieties and others which are highly susceptible to powdery mildew should be dusted with sulfur at the first sign of the disease and a repeat application made in 10 days.

The Grape Spray Residue Problem

In general, the spray residue situation with grapes in some districts is essentially the same as with apples in localities where repeated sprays must be applied to produce fruit free from insect damage. The same problems are presented in keeping the residue content of arsenious oxide below the legal tolerance. With sprays for grapes, however, special

difficulties are presented. Poison in sufficient quantities to prevent berry-worm injury must be kept on the fruit over a long period, but spray mixtures adhere poorly to the waxy skin of the berries. An adhesive, such as fish-oil soap, is necessary in the mixture to secure adequate coverage of the berries and retention of arsenicals if these are used. This complicates the cleaning problem, since residue removal is made more difficult. The surface area of a given quantity of grapes is greater than with the same quantity of apples, and the stems and closely packed berries favor clotting and retention of residue. Treatment for residue removal from grapes is more difficult than similar treatment of apples, because of the highly perishable nature of the fruit.

Table 16

SPRAY PROGRAM FOR AMERICAN-TYPE GRAPES

Time	*Materials*	*Disease or Insect*	*Remarks*
When new shoots are 7–8 inches long	6-8-100* Bordeaux mixture	Fungous diseases	In areas where black rot is serious it is wise to make a similar application when the young shoots are 1–2 inches long
Just before bloom	6-8-100 Bordeaux mixture and 50 per cent DDT wettable spray powder two pounds	Fungous diseases and grapeberry moth	
Just after the blossoms fall	ditto	ditto	
Two weeks later	ditto	Fungous diseases, grape leafhoppers	Direct spray against lower surface of leaves
2–3 weeks later, or when fruit is about half-grown	6-8-100 Bordeaux mixture	Black rot and other diseases	

* In Ontario, Canada, the corresponding formula is 7½-10-100.

2. Strawberry Culture

THE INDUSTRY, REGIONS, AND DISTRICTS

THE TOTAL commercial acreage of strawberries in the United States and Canada is about 250,000 acres as a normal yearly level.

Early-crop Regions and Districts

FLORIDA. Strawberry growing is of major horticultural importance in Florida. In the peak years 1937–38 the acreage was 11,000 acres, but considerable reduction has occurred subsequently. The two chief districts are in Hillsborough and Polk Counties in south-central Florida, and in Bradford County in the northern part. In the south-central section, Plant City and Lakeland and, in the northern section, Lawtey and Starke, are the chief centers. Shipment in the Plant City-Lakeland area extends from December into April and in the Starke-Lawtey area from March into May. Florida strawberries often ripen in very cool weather. The Missionary variety has been grown almost exclusively.

ALABAMA. The state is divided into three districts: southern, central, and northern. The total acreage is about 7,500 acres.* Shipments in the three districts begin about April 1, 15, and 25, respectively. The southern district comprises areas in Butler, Conecuh, and Escambia Counties and points between Montgomery and Atmore. Castleberry, Conecuh County, is the chief shipping point. The central district comprises areas in Autauga, Chilton, and Sumter Counties and points between Montgomery and Birmingham, such as Thorsby, Jemison, and Clanton. The northern district comprises areas in Cherokee, Cullman, Etowah, Mor-

* This and other acreages mentioned for the various areas will vary from year to year but the figures are set forth as reasonably representative in a comparative way.

gan, and Marshall Counties and points north of Birmingham, such as Cullman. The acreage around Cullman is about 1,500 acres.

LOUISIANA. Strawberry growing is one of the leading agricultural industries in the state. The market-strawberry area averages about 20,000 acres and is situated mostly in the southeastern section, in Tangipahoa, Livingston, and St. Helena Parishes. The total value of the crop, including the cold pack and local sales, is about $10,000,000. Hammond,* Independence, Amite, Ponchatoula, and Tickfaw are important shipping points in Tangipahoa Parish. Albany and Denham Springs in Livingston Parish, and Montpelier in St. Helena Parish, are other centers. Louisiana leads all other states in the carlot shipment of strawberries. About 2,500 cars or carlot equivalents are moved from the Tangipahoa Parish section each year, with about 12 per cent of the total tonnage being shipped by truck.

MISSISSIPPI. The three chief sections are: north—Panola County; east-central—Lauderdale County; and south—Covington, Pearl River, and Harrison Counties. First shipments are made from the coastal counties of Harrison and Pearl River about April 1. An important shipping point is Picayune, where concentration is made from nearby points and also from the Bay St. Louis and Bogalusa, La., sections and sometimes from Long Beach. Carlot shipments from Sanford, Brookhaven, Waynesboro, Meridian, Marion, and Durant start about April 15. From Tupelo, Amory, Batesville, and Corinth, berries are shipped a week to 10 days later.

TEXAS. Important acreages are in south Texas in the San Antonio and Houston districts. Harris County, adjacent to Houston city, is the leading area. Pasadena, in this county, is the chief shipping point. The production in southwest Texas amounts to about a third of the state total and about 1910, under irrigation, enough was grown in the Lower Rio Grande Valley to supply local markets. Later production has been mostly around Poteet, in Atascosa County, and near Carrizo Springs in Dimmit County. The Tyler district in Smith County in the northeast timber country is an important one. The total commercial acreage is about 3,000 acres.

* Though Hammond is mentioned as a chief center, it produces only a small proportion of the crop, the acreage being scattered throughout several counties containing many loading stations. Hammond, however, is the location of the auctions (see later) that handle practically the entire crop of the section. Marketing usually begins in late March.

Second-early-crop Regions and Districts

Arkansas. There are four districts, as follows: southwest, White County, west-central, and northwest. White County is the most important, followed closely by the northwest district. Shipments from a total of about 20,000 acres begin about April 20 in the southwest district, April 25 to May 1 in White County and the west-central district, and May 1–5 in the northwest district.

The southwest district centers in Sevier County and comprises points such as Horatio, DeQueen, Wickes, and Gillham. The White County district extends from Cabot to Bradford and centers around Bald Knob and Judsonia where the industry in this area began. Probably more strawberry plants are shipped yearly from Judsonia than from any other town in the world. An average year's business for Judsonia is 40,000,000 plants. Plants have been sent out in solid carloads. The west-central district centers at Van Buren in Crawford County, and the northwest district at points such as Springdale and Fayetteville in Benton and Washington Counties.

North Carolina and South Carolina. These two are combined because the acreage occurs in the eastern part of both states and is separated only by the state line. The larger part (about 6,000 acres) of the acreage is in North Carolina; about 500 commercial acres occur in South Carolina. Chadbourn, in North Carolina, is the next big shipping section along the Atlantic Coast after the Florida crop. In South Carolina, the chief points are Loris and Conway in Horry County. Marketing begins about mid-April.

Tennessee. There are three production sections: western, shipping about April 19 to May 1; eastern, shipping May 1–10; and central, shipping about May 15. The western section ships about twice as much as the other two combined, and the eastern section nearly twice as much as the central. The total for the three sections is about 15,000 acres.

The western section is mostly in Gibson, Crockett, Lauderdale, Madison, Carroll, Weakley, and Dyer Counties and comprises points as follows: Humboldt, Jackson, Trenton, Dyer, Rutherford, Kenton, Milan, Trezevant, Medina, McKenzie, Ripley, Halls, Carve, Bells, Gadsden, Brownsville, Newbern, Sharon, and Greenfield.

The eastern section is mostly in Rhea, Hamilton, Meigs, and Bradley Counties and comprises points from Chattanooga north to Harriman,

such as Boyce, Daisy, Dayton, Evensville, Rathburn, Sale Creek, and Spring City; and from Chattanooga east to Knoxville, including Cleveland, Armona, and Maryville.

The central section is north of Nashville, mostly in Summer County, and comprises points such as Portland, Mitchellville, Fountain Head, Westmoreland, and Lawrenceburg, in Lawrence County.

VIRGINIA. The leaders are the Norfolk district in the southeastern part of the state and the Eastern Shore district, on the peninsula east of Chesapeake Bay. Some chief points are Onley, Melfa, Painter, and Makemie Park in Accomac County; Port Norfolk, in Norfolk County; and Bayview, in Northampton County. The total acreage is about 7,000 acres. Marketing begins about May 1 to May 10.

INTERMEDIATE-CROP REGIONS AND DISTRICTS

DELAWARE. The chief district is in Sussex County. Some leading points are Roxana, Selbyville, Bridgeville, Millsboro, Laurel, Greenwood, and Georgetown. Picking, from about 4,000 acres, extends from about May 15 to June 30.

NEW JERSEY. The leading areas are the Cumberland County district, and the Burlington and Camden district. Market acreages, to the extent of 4,000 acres, are scattered throughout the state, but the chief section is situated in the southern half. Cedarville, Cumberland County, is the chief shipping center. Marketing begins in late May.

MARYLAND. Counties on the east side of Chesapeake Bay, which are part of the Eastern Shore district, include the chief acreages. Some important points are Federalsburg, Goldsboro, Hillsboro, Salisbury, Marion, Pittsville, Fruitland, Berlin, and Crisfield. Salisbury is also one of the leading strawberry plant centers in the United States. Marketing, from about 7,000 acres, begins about May 15.

KENTUCKY. The chief district is at the southern boundary of the western part of the state. About 75 per cent of the acreage is located around Paducah, in McCracken, Ballard, Marshall, and Graves Counties. Other points are Franklin, Oakland, Bowling Green, Russellville, Woodburn, Pembroke, Hopkinsville, and Bristow. Some of these form a continuation of the central section of Tennessee. Another district is near Louisville in west-central Kentucky. Marketing, from about 8,000 acres, usually is from May 5 to June 15.

INDIANA. The chief shipping area is in extreme southern Indiana around Borden and Floyds Knobs where Aroma has been the leading variety. Marketing, from about 3,000 acres, usually begins about May 15.

ILLINOIS. Apples and peaches are the only Illinois fruits whose commercial value exceeds that of the strawberry. The chief strawberry area is in Pulaski, Union, Jackson, and Massac Counties, in the extreme southern part of the state. The Cobden-Anna area is an important center. An important area also is in south-central Illinois, in Fayette, Marion, Washington, and Jefferson Counties. In Edgar County, east-central Illinois, there are about 1,000 acres of strawberries; the industry centers at Paris. Marketing usually begins in May, with the greatest movement in June. Most of the crop is trucked to Chicago. Some other important points are Villa Ridge, Pulaski, Fayette, Quincy, Ullin, and Makanda. The total acreage is about 4,500 acres.

KANSAS. Doniphan County, in the northeastern part of the state, is the chief section; the center is at Wathena. Marketing, from about 1,200 acres, usually extends from May 20 to June 30.

MISSOURI. Southwestern Missouri and northwestern Arkansas are known as the Ozark region. The southwest district, which centers at Monett, ranks first; Monett is the sales point for about 15,000 acres within a radius of 20 miles. The industry was started commercially in 1887 at Sarcoxie; two years later the first carlot shipping association was organized. From then on the industry expanded, reaching its peak (27,340 acres for the state) in 1927, but has subsequently declined considerably. The two big gateway markets are St. Louis and Kansas City, whence the berries are diverted to markets elsewhere. Shipments start about May 10 to May 15. Some chief points are: Monett, Sarcoxie, Neosho, Anderson, Larussell, Republic, Washburn, Aurora, Carthage, Purdy, Butterfield, Wheaton, Exeter, Cassville, Stotts City, Pierce City, and Joplin.

A much smaller area occurs in eastern Missouri in St. Louis and Jefferson Counties.

IOWA. The chief area is near Fort Madison in Lee County in the southeastern part of the state. The total acreage is about 1,300 acres.

CALIFORNIA. The commercial acreage is roughly divided into five districts: Central Coast, Sacramento County, San Joaquin Valley, Los

Angeles, and other southern areas. The total acreage is about 7,000 acres. The Imperial Valley produces the earliest crop, beginning in late January or early February, extending through March and into early April; a second crop matures in May. The Los Angeles district follows the Imperial, with a small crop in January and February of some years, but with the main crop starting in March, reaching a peak in April, and ending in May. A second crop matures in June and July. The San Joaquin Valley follows the Los Angeles district in the spring shipments by 10–14 days. The Sacramento district is a week later than the San Joaquin. Shipments from these interior-valley districts extend to July or August, when the second crop normally ends. The Central Coast district begins shipping at about the same time as the Sacramento Valley.

Unlike other districts the Central Coast produces continuously until late fall, but the peak is in late May. Production finally ceases with the advent of cold weather in very late fall but usually some berries are harvested until Thanksgiving or later, and occasionally until Christmas. In no other state is the strawberry harvested every month of the year. Because of the more or less continual bearing habit, in the Central Coast district, yields per acre are extremely high and cause a high state average yield.

OKLAHOMA. The industry is confined mostly to Adair and Cherokee Counties in the northeastern portion. The area at Wyandotte in Ottawa County is also important. The total acreage is about 1,000 acres.

LATE-CROP REGIONS AND DISTRICTS

NEW YORK. Market acreages, about 4,000 acres, occur in the Hudson River Valley and near Lake Ontario and Lake Erie. Important points are: Germantown, Columbia County; Tivoli, Dutchess County; Richland, Oswego County; and Marlboro, Ulster County. Growers in Oswego County make a specialty of late berries for New York City. The most intensive area is in Erie and Chautauqua Counties near Buffalo, centering at Brant and North Collins. Around many of the larger cities, such as Rochester, Schenectady, and Utica, are scattered plantings.

PENNSYLVANIA. The three leading districts are: Erie County, in the northwestern part of the state; around Pittsburgh; and in the southeastern section, near Philadelphia. The latter is the largest. The total acreage is about 4,000 acres.

OHIO. The area bordering Lake Erie, comprising Ashtabula, Lake, Cuyahoga, Lorain, Erie, Sandusky, and Lucas Counties, is the leader, and the total acreage is about 5,000 acres. The chief market is Cleveland. Appreciable acreages occur throughout the state, chiefly near Cincinnati, Columbus, Akron, Canton, Dayton, and Youngstown and in Lawrence County in southeastern Ohio.

MICHIGAN. The chief acreage is in southwestern Michigan, centering at Benton Harbor, and northward near Lake Michigan. A later ripening but smaller area occurs near Cadillac, in north-central Michigan; and a very late, but still smaller area, which is known as the "Far North," centers at Marquette. The total acreage is about 8,000 acres.

WISCONSIN. The strawberry is the chief small fruit in the state. The main areas are in Bayfield County in the northern part of the state and in the southwestern part. Commercial canning is done at Sparta, in Monroe County. Duluth, Milwaukee, and Chicago are the chief markets. The total acreage is about 2,000 acres.

MINNESOTA. Hennepin County produces locally grown berries for the cities of Minneapolis and St. Paul.

COLORADO. Commercial production is found primarily in the area around Denver. Irrigation is essential.

IDAHO. Strawberries are grown both under irrigated and dryland conditions. The Boise and Payette valleys are leading areas. In the Snake River Valley chlorotic conditions often arise (see Soil Reaction).

WASHINGTON. The southwestern district in Washington and the northwestern district in Oregon may be considered, in large part, as one district, though the Columbia River divides the two. The chief counties in Washington are Thurston, Clark, Lewis, Snohomish, Spokane, Pierce, King, and Kitsap, in about the order named. The bulk of the western Washington production, aside from what is consumed in the northwestern centers, is processed, and the selection of varieties is based on their suitability for canning and freezing. In eastern Washington, strawberries are produced in the Spokane section where late ripening enables the growers to avoid the main season competition. Kennewick, combined with the shipping point of Pasco just across the river, ships the earliest strawberries grown in Washington. The total acreage is about 10,000 acres. The hill system is used in western Washington and the matted row in most other districts of the state.

OREGON. Strawberries, the chief small fruit grown in Oregon, are produced commercially in 33 of the 36 counties. The value of the farm marketings is between $2,000,000 and $3,000,000. The main areas, 13,500 acres peak in 1941, are in the Willamette Valley in Marion, Clackamas, and Multnomah Counties.

The Willamette Valley is bounded on the north by the Columbia River and extends south approximately 150 miles. It is bounded on the east by the Cascade Range and on the west by the Coast Range. The valley floor averages about 25 miles wide. The total average rainfall is about 42 inches and occurs mostly in fall, winter, and spring. July and August, however, are near drought months, the total precipitation in this two-month period usually averaging less than two inches. The soils vary widely due to parent materials, texture, depth, and drainage.

CANADA

Annual production of strawberries in Canada is about 25,000,000 quarts, according to provinces as follows: Ontario, 10,000,000 quarts; British Columbia, 8,000,000 quarts; Quebec, 5,000,000 quarts; New Brunswick, 1,000,000 quarts; and Nova Scotia, 1,000,000 quarts.

ONTARIO. Ontario, with a total of about 7,000 acres of strawberries, is divided roughly into three main commercial sections: the Simcoe and Waterford districts in Norfolk County and adjacent areas in Brant County on the north and Elgin County on the west; the Burlington, Oakville, and Clarkson districts in Halton and Peel Counties; and the Niagara district in Lincoln and Wentworth Counties, where first pickings of Premier are made about June 12. These three sections comprise 60 to 70 per cent of the Ontario strawberry acreage.

A modern precooling and cold storage plant was built at Simcoe, Norfolk County in 1930, and with subsequent additions now has storage space for 300,000 bushels of apples. During the summer, it is the headquarters for the marketing of strawberries and raspberries, where facilities are available for precooling, grading, and shipping. Some 60 to 75 per cent of the strawberries used in the processing and production of jams and preserves in Ontario is produced in Norfolk County, as well as a large volume for the fresh fruit market. Norfolk County is also the leading source of strawberry plants in Ontario. The distribution of the Ontario crop production may be given as east of Toronto (43 per cent of the acreage and 18 per cent of the crop) and west of Toronto (57 per cent of the acreage and 82 per cent of the crop).

BRITISH COLUMBIA. The chief districts are as follows:

VANCOUVER ISLAND AND GULF ISLANDS. The southern end of Vancouver Island, comprising the local districts of Gordon Head and Keating, adjacent to Victoria city, and situated on the Saanich Peninsula, is one of the oldest districts. The fruit is shipped in refrigerator cars to the markets of the Prairie Provinces or sold to local markets, canneries, jam factories, and for quick freezing. A considerable tonnage has been processed by the SO_2 method for export to the British Isles. In the districts adjacent to Victoria it has been necessary to ship carload lots via the Esquimalt and Nanaimo Railway to Ladysmith and from there by barge to Vancouver where the fruit is shipped to prairie points via the CPR, or via CNR barge service to Port Mann and thence east by rail.

LOWER MAINLAND. This district is continuous to the Fraser River from its mouth on the west to Agassiz and Chilliwack on the east, and including Burnaby, Hammond, Haney, Whonnock, Mission, Hatzic, Dewdney, and Agassiz on the north side of the Fraser River and Chilliwack, Abbotsford, Matsqui, Langley, Surrey, and Delta on the south side. These localities are more favorably situated as regards transportation facilities than the areas on Vancouver Island, being mostly located on the main line of the CPR. The areas on the south side of the river are served by the main line of the CNR. There are about 2,500 acres of strawberries in the Lower Mainland.

SALMON ARM. This district is well served by the main line of the CPR, 315 miles east of Vancouver.

OKANAGAN VALLEY. This is essentially an irrigated tree-fruit district. Strawberry-growing is not extensive and centers chiefly around Armstrong at the northern end of the valley.

WEST KOOTENAY. The center is at Wynndel. This district is on the Crowsnest line of the CPR. Strawberries ripen later in this area than at the Coast and do not come in direct competition with the Coast fruit on the Prairie markets.

TERRACE-SKEENA RIVER. This district is situated on the CNR, 95 miles east of Prince Rupert. On the opposite side of the Skeena River, Reno, 8 miles west of Terrace, is another small area.

QUEBEC AND MARITIMES. There are about 3,000 acres of commercial strawberries in Quebec, and 600 in each of Nova Scotia and New Brunswick.

DEVELOPMENT OF STRAWBERRY VARIETIES*

Development of Standard Varieties

Derivation of the Strawberry. The evidence concerning the derivation of the cultivated strawberry favors the hypothesis of a cross of two American species *Fragaria chilensis* (beach or West Coast strawberry) and *F. virginiana* (meadow strawberry) and is summarized as follows:[196] (a) It first appeared in Europe in a region where the pistillate form of *F. chilensis* and the hermaphroditic form of *F. virginiana* had been grown together in gardens for a number of years. (b) It has the same chromosome number, 28 pairs, as these species and is fully fertile with them. (c) It differs in chromosome number from the European species, *F. vesca* (Alpine or Wood strawberry), 7 pairs, and *F. elatior*, 21 pairs, and crosses with these species give sterile hybrids. Discovery of a few fertile seedlings in crosses of a pistillate form of *F. virginiana* and the *F. moschata* varieties Black Hautbois and Montreuse Hautbois indicates[196] that *F. moschata* may have entered into the development of the modern strawberry.

Earliest Varieties. Perhaps the year 1800 is as accurate as any to give as the start of the strawberry industry in America. By 1825, Large Early Scarlet, Hudson Bay, Early Hudson, and Crimson Cone were produced commercially near Boston, New York, Philadelphia, and Baltimore. Keen's Seedling, which originated in 1818 and was imported from Europe about 1824, was the most popular variety between 1830 and 1840.

Hovey. The first great American strawberry was Hovey, the result of and the forerunner of purposeful breeding. It originated in 1834, was introduced in 1838, became a standard around Boston though a capricious sort elsewhere, and remained as such until about 1880. Boston Pine, between 1850 and 1865, was much planted as a companion for Hovey. Black Prince, which was possibly a parent of Wilson, was widely grown between 1840 and 1855. Crimson Cone (Hackensacks) was a leader near New York City from 1840 to 1860.

Wilson and Later Varieties. Wilson became outstanding after Hovey. It originated in 1851, was introduced in 1854, and generally monopolized the market between 1860 and 1875. Its reign extended some 10 years longer, but during this period it shared popularity with Crescent

* The origin of additional varieties is given under Characteristics.

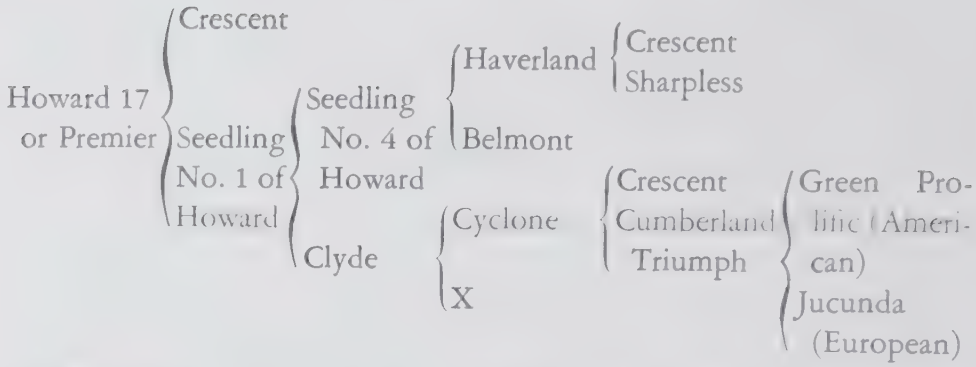
which was introduced in 1870 and which, in turn, frequently with Sharpless or Captain Jack as a pollinator, dominated all markets until 1890. Jucunda produced remarkable yields near Pittsburgh between 1860 and 1871. Agriculturist and Downer's Prolific assumed some prominence between 1865 and 1875, as did Charles Downing, Cumberland Triumph, Neunan, and Cloud between 1870 and 1895.

With the introduction of Wilson, strawberry growing in New Jersey began to shift from the vicinity of New York to southern New Jersey. After the Civil War, boat shipments of strawberries from Norfolk, Va., were sent to New York. At this time, strawberry growing also began to develop rapidly in the Delaware and Maryland peninsula, and southwestern Michigan and southern Illinois began supplying the Chicago market. The rapid extension of railroads and the introduction of refrigeration in transit led to the further extension of strawberry growing into Tennessee, central Arkansas, Louisiana, and northern Florida between 1870 and 1890. Since 1890, North Carolina, central Florida, Alabama, the Ozark region of Arkansas and Missouri, the Santa Clara Valley of California, and the Pacific Northwest have become important strawberry-growing regions.

Between 1890 and 1905, Bubach in the East, Captain Jack in the Rocky Mountain States, Arizona in certain irrigated sections of the Pacific Northwest, and Parker Earle in the West, assumed importance. In 1893, Australian became the leading variety near Los Angeles in California, being superseded later by Brandywine. Clyde and Kentucky were largely grown in the East about this time. Gandy soon became a standard late variety after being introduced in 1888, superseding its parent Glendale. Warfield, which was introduced in 1885, largely superseded Crescent, and as an early berry it assumed leading rank between 1890 and 1900. Beder Wood was a popular pollinator for the Warfield. The "Big Four" of this period were Crescent, Bubach, Haverland, and Warfield.

Aroma was introduced in 1892. In the same year, in England, Thomas Laxton introduced the Royal Sovereign.

Senator Dunlap, introduced in 1900, soon became the most widely grown variety in the North-Central States. Howard 17 (Premier) introduced in 1909 became the leading variety in northern regions. The following chart shows the ancestry of this variety and its development by A. B. Howard & Son, Belchertown, Mass., from older varieties.



Klondike, introduced in 1901, supplanted Michael (prominent in 1897), Thompson (a standard between 1898 and 1910), Excelsior (which appeared about 1900), and other varieties in the South for shipment.

In the West, especially in the Hood River Valley of Oregon, Clark (introduced about 1880), Ettersburg 121, Marshall, and Oregon supplanted Triomphe, which had become a favorite there following wide planting in the East between 1860 and 1870.

Chesapeake, introduced in 1906, rapidly attained favor along the Atlantic seaboard. Hoffman (seedling of Neunan) became the chief variety in many of the South Atlantic and Gulf States from 1880 to 1905. Missionary was introduced in 1906.

A list including 1,879 strawberry names was published in 1916.[219] This number has increased greatly, and possibly 5,000 could be included at the present time. The leading varieties are discussed later.

Development of Fall-bearing Varieties

Bismarck (Van Deman x Bubach), introduced about 1895, is the reputed parent of Pan-American, which was found in 1898 by Samuel Cooper, Delevan, N. Y. The latter is considered as the first of the race of North American "everbearing" varieties. For a number of years, interest in everbearers centered around the breeding work of Mr. Cooper and Harlow Rockhill, Conrad, Ia. Mr. Cooper introduced the Pan-American, Superb, and several others. Mr. Rockhill introduced the Americus (Pan-American x Dunlap) in 1911, the Progressive (Pan-American x Dunlap) in 1912, and later the Rockhill (Progressive x Early Jersey). Fred Braden, in Minnesota, reselected the Wayzata from mixed stock of the Rockhill. Beginning about 1925, the Mastodon, which originated in Indiana, assumed importance.

More recent introductions are Gem, Paymaster, Green Mountain, and Streamliner. Green Mountain (Patent No. 112) is an open pollinated seedling of Superb which originated with G. D. Aiken, Putney, Vt., and was introduced commercially in 1935. Streamliner, of unknown parentage, originated with R. C. Edgmand, Lostine, Ore., and was introduced commercially in 1944.

Characteristics of Strawberry Varieties

Aroma. Exceptionally good shipper and hence has been a very important variety in America but is now largely superseded by newer varieties. Berries wedge-conic in shape, light red, quality only fair. Later than Klondike, Missionary, Blakemore, and Premier, when grown in the same territory. Origin—with E. W. Cruse, Leavenworth, Kans., about 1889; seedling of Cumberland Triumph.

Beaver. Highly regarded in Wisconsin and Minnesota for its early, well-colored berries of good handling quality. Origin—with Jeff Beaver, Eau Claire, Wis.

Blakemore. Berry light red, uniformly colored to the center; below medium size; firm; rather acid. Vigorous plant maker, and the number of new plants from runners must be restricted in the row. Adapted to the regions where the Missionary and Klondike, and to some extent Aroma, have been grown. Ripens early. Excellent for preserving. Origin—Missionary x Premier in 1923 at the U.S. Field Station, Glenn Dale, Md.

Brightmore. In Pacific Coast districts it is a firm, bright-red variety especially well adapted for freezing and preserving. Origin—Oregon Experiment Station; Blakemore x (Ettersburg 121 x Marshall) in 1932; introduced in 1942.

British Sovereign. The chief variety in British Columbia, under the hill system. Origin—British Columbia. In 1920 a Japanese grower of Coghlan, B. C., purchased some Campbell (Paxton) plants from Queensborough, Lulu Island. Six plants were noted to be different; they were allowed to produce runners and were kept separate. Named in 1929, "British" for British Columbia and "Sovereign" because the flavor and quality were sufficiently high to rate it with the Old Country variety Royal Sovereign. Actually, however, the variety is not related to Royal Sovereign.

Catskill. Berries large, roughly round conic, bright red, good quality, medium firm. Plants highly leaf-spot resistant, produce many runners. Ripens in early midseason, during the latter part of the Premier season. Ranks higher than most varieties in vitamin C content. Origin—Experiment Station, Geneva, N. Y.; Marshall x Howard in 1923.

Chesapeake. A showy, high quality, late midseason variety that makes few runners and requires close planting. Perhaps does best only under irrigation and on sandy soil in northeastern United States, though in some sections in Maryland, Delaware, and New Jersey it is grown profitably without irrigation. The "aristocrat;" of strawberries. Origin—with J. W. Parks, Nanticoke, Md., about 1904; chance seedling.

Clark. This midseason variety with firm, attractive, dark berries has been

important for shipping and canning in the Hood River and White Salmon regions of the Pacific Northwest. Origin—with F. E. Clark, Portland, Ore., about 1880; probably a seedling of Wilson.

CRIMSON GLOW. Fruit medium red color, firm, late midseason. Origin—New Jersey Experiment Station.

CORVALLIS. Best adapted to the river bottoms in the Willamette Valley, Ore., where its yields have been 3–5 tons per acre. Good for canning and freezing but unsuited to long-distance shipping. Origin—Oregon Experiment Station; Ettersburg 121 x Marshall in 1921; introduced in 1930.

DOLLAR. Important near Sacramento, Calif., where it is liked because of its firm fruit and attractive color and because the plants bear steadily from about April 20 to late summer and fall. Origin—with O. F. Felton, Merchantville, N. J., about 1885.

DORSETT. Berry of good size and bright color and maintains its attractiveness longer than darker sorts; fine dessert quality. Often not a high yielder. Origin—U.S. Dept. of Agriculture; Howard 17 (Premier) x Royal Sovereign in 1923.

DRESDEN. Berries large, uniform, regular, conic, bright light red, fair quality, medium firm. Plants vigorous, very productive, free from leaf spot. Early; the size of berries holds up well and the picking season extends a little later than that of Premier. Origin—Experiment Station, Geneva, N. Y.; Beacon x Howard 17 in 1929; introduced in 1939.

DUNLAP (Senator Dunlap). Fruit conical, necked; medium to small; soft; rich red; fine grained; high quality. Very prolific plant maker; plants small. Early midseason. Its best adaptation is in the colder regions. The notes also apply to the Dr. Burrill variety. Origin—with J. R. Reasoner, Urbana, Ill., about 1890; parentage uncertain, Cumberland Triumph, Windsor, and Sucker State are possibilities.

ETTERSBURG 121. Grown chiefly in western Oregon for canning; not adapted to the east. Origin—with A. F. Etter, Ettersburg, Calif., in 1905.

FAIRFAX. Berries medium early, large, wedge-conic shape, bright red when first ripe and soon turn to deep red, flesh firm, excellent dessert quality. Plants vigorous and form many runners which often require thinning. Especially suited to the home garden. Origin—U.S. Dept. of Agriculture; Royal Sovereign x Premier in 1923.

FAIRMORE. Grown to some extent in the South. Origin—U.S. Dept. of Agriculture; Fairfax x Blakemore; introduced in 1939.

GANDY. Berry large, irregular, inclined to be hollow at the core, late. Origin—with W. G. Cancy, Newport, N. J., in 1885. Glenndale x Jersey Queen.

GEM. Fall bearing. Berry large, light red. Sets runners well for this type. Origin—with F. J. Keflinger, Farwell, Mich., in 1933.

GIBSON. See Parsons.

GLEN MARY. Berry frequently with light-colored tips. Early blossoms hardly produce enough pollen for themselves. Production somewhat unreliable. Grown chiefly in New York and New England. Origin—with J. A. Ingram, East Bradford, Pa., in 1896; chance seedling near plants of Crescent, Downer's Prolific, and Sharpless.

HEFLIN. A very early, bright red berry, with rather soft, light-colored flesh, grown chiefly in the Eastern Shore section of Virginia. Origin—North Carolina, about 1902.

HOWARD, Howard 17 (Premier). It is grown chiefly in New England, southward to Virginia, and northward and westward to Illinois, Michigan, and eastern Canada. Fruit ripens in early midseason, is attractive, and of good quality, but only fairly firm. The plants are highly productive and free from foliage diseases. The variety is often only a fair plant maker. Origin—with A. B. Howard & Son, Belchertown, Mass. (See also earlier.)

JOE. A late midseason variety, with large attractive berries that find favor for shipment. Grown chiefly in Maryland, New Jersey, Delaware, and Pennsylvania. Origin—with Black, Son & Co., Hightstown, N. J.; seedling of Gandy.

KLONDIKE. A leading variety because of the large acreage in southern states. Primarily a shipping berry. Its clear color does not darken or fade readily. Not suitable for northern regions. Origin—with R. S. Cloud, Independence, La.; Pickerproof x Hoffman.

KLONMORE. It comprises a considerable portion of the Louisiana acreage. Compared with Klondike, it resists leaf diseases better, is of superior dessert and shipping quality, and it produces earlier yields and continues to produce fruit later in the season. Klonmore plants are very vigorous and well adapted to the system of producing plants in Louisiana. Origin—Klondike x Blakemore; introduced by Louisiana State University Experiment Station in 1940.

KONVOY. High yielder; resists leafspot and scorch. Origin—Fairmore x Klondike; introduced by Louisiana State University Experiment Station in 1942.

LUPTON. A showy midseason berry of poor quality. Plants susceptible to leafspot diseases. Grown chiefly in southern New Jersey. Origin—introduced by M. D. Lupton, Newport, N. J., in 1915.

MAGOON. A soft, midseason berry which is productive and liked for home use and local market in the Willamette Valley of Oregon and in western Washington. Origin—with W. J. Magoon, Portland, Ore.; chance seedling.

MARSHALL. A high quality dessert berry and therefore favored to a certain extent in New England and New York but subject to leaf-spot diseases. Grown extensively in Oregon and Washington for commercial preserving and in California where it fruits throughout the summer. Origin—with M. F. Ewell, Marshfield, Mass.; chance seedling.

MASSEY. A superior variety in North Carolina for the fancy trade. Origin—U.S. Dept. of Agriculture; (Royal Sovereign) x Blakemore in 1933.

MASTODON. Fall-bearing. Low rich soil seems best for it. Subject to leaf diseases. The yield of the fall-bearing varieties is less for the season than that of the standard sorts, and picking is required over several months instead of several weeks. The objections exceed the advantages in most cases. Origin—with Geo. Voer, Peru, Indiana; Superb x Kellogg Prize.

MAYTIME. Earliest variety of high quality in Maryland. Recommended for trial from Virginia to southern New Jersey and westward to Oklahoma and Kansas. Origin—U.S. Dept. of Agriculture; Missionary x Fairfax in 1931; introduced in 1940.

MISSIONARY. A firm, attractive, productive berry with foliage free from leafspot diseases. Ripens from December until April in central Florida where it is extensively grown; also widely grown in eastern North Carolina, the Norfolk district of Virginia, and some parts of eastern Maryland. Rather too soft in other

Outspreading (*left*) and appressed (*right*) pubescence on the pedicel. (Pedicel is the stem supporting individual berries.) Some varieties with outspreading pubescence are Aroma and Parsons; some with the appressed type are Klondike, Premier, Missionary, Chesapeake, Dunlap, and Gandy.

shipping sections. Origin—chance seedling with Nathaniel Gohn, Deepcreek, Va., about 1900.

NARCISSA. More highly productive, firmer, and more uniform than Marshall in the Pacific Northwest, though not quite so large. Good for preserving or other processing. Origin—U.S. Dept. of Agriculture; Royal Sovereign x Howard 17 in 1923.

OREGON. Similar to Banner and Marshall.

PARSONS. Gibson, Pocomoke. A dependable, productive berry in northern regions where it is much used for preserving. Fruit briskly subacid; dark; soon becomes unattractive in appearance. Origin—with R. G. Parsons, Parsonsburg, Md., about 1890; chance seedling.

PATHFINDER. Berries large, round to round-conic, bright light to medium red, good quality, only medium firm. Plants vigorous, form many runners, and are productive. A little later than Premier. Resistant to red stele. Origin—New Jersey Experiment Station; Howard 17 x Aberdeen; named in 1938.

PREMIER. See Howard. The story is that Howard seedling No. 17 found its way into the hands of a nurseryman before it was named and then appeared in the trade as Premier.

REDHEART. It is primarily a canning berry of deep red color, high quality, and firm texture and is adapted to the Pacific Northwest rather than to eastern regions. Origin—Portia x Euresko in 1923 at U.S. Field Station, Glenn Dale, Md.

REDSTAR. Very late. For trial in northern states as far south as Virginia and west to Missouri. Origin—U.S. Dept. of Agriculture; Chesapeake x Fairfax in 1931; introduced in 1940.

REDWING. A good plant maker. Fruit medium to large and of medium dark-

red color. Moderately firm and of good quality. Yields well. Ripens late mid season. Origin—New Jersey Experiment Station.

SAMPLE. Pistillate. A late midseason variety planted to some extent, with one or more varieties as pollinizers, in northern, midwestern, and eastern regions. Origin—with J. D. Gowing, North Reading, Mass., in 1894, chance seedling, possibly of Leader. (Very few imperfect varieties are commercially important.)

SPARKLE. Prolific plant maker. Berries late midseason, glossy, bright. Resistant to red stele. Origin—N. J. Experiment Station; Fairfax x Aberdeen in 1931, distributed in 1942.

STARBRIGHT. For trial for the general markets from Virginia to New Jersey and westward to Kansas and Iowa. Origin—U.S. Dept. of Agriculture; Chesapeake x Fairfax in 1931; introduced in 1940.

TEMPLE. Vigorous, tall plants. Resistant to red stele. Slightly later than Blakemore. Berries blunt conic. Origin—U.S. Dept. of Agriculture; Aberdeen x Fairfax in 1938; selected by Dr. Temple and named after him.

TENNESSEE BEAUTY. Midseason to late; large, very attractive, firm berries. Origin—Tennessee Experiment Station; Missionary x Premier; introduced in 1942.

TENNESSEE SHIPPER. Early; very firm and good shipping qualities. Origin—Tennessee Experiment Station; Missionary x Blakemore; introduced in 1941.

TENESSEE SUPREME. Medium early; high quality; especially valuable for quick freezing. Origin—Tennessee Experiment Station; Missionary x Premier; introduced in 1940.

VALENTINE. Its roots are long and deep which helps it to withstand drought conditions. Early; a full picking ahead of Premier, and rots less in wet seasons. A good cropper, and the fruit is very firm, of fair to good quality, bright, attractive, but apt to be too dark for some markets. It holds its size well over a long season. As a canned berry it retains its shape and color better than do most varieties; also it makes a very fine jam. Origin—Horticultural Experiment Station, Vineland, Ont., in 1927; Premier x Vanguard (Pocomoke x Early Ozark), named in 1941.

DURATION OF STRAWBERRY PLANTING, YIELDS, AND COSTS

Many strawberry growers crop the planting only once and then turn it under. With such a practice new plants are set each year, entailing the expense of the plants, setting, and care for every crop obtained, and two years' use of the land for only one crop. Frequently, however, fruiting the commercial planting once only is best.

Much too often with a second crop, the yield is low, the berries decrease rapidly in size and are of poor appearance, picking is slow and tedious, heaving out materially reduces the stand, diseases and insects become serious, and drought causes much damage. If the planting has been carefully handled and weeded and is in good condition when the first crop is harvested, it will probably be profitable to continue the plant-

ing for a second crop. Success with a second crop reduces production costs; also, second-crop berries usually ripen slightly earlier than do first-crop berries.

In many cases, plantings are neglected after one or more crops, the grower reasoning that any fruit picked thereafter is produced with little expense and any fruit sold is so much gained. Sometimes, neglected or haphazardly renewed beds produce enough fruit to be worth picking, but commercially the fact that the land might be used more profitably for

Table 17

EFFECT OF YIELD ON STRAWBERRY COSTS. MICHIGAN[531]

Item	*Crates per Acre*		
	Under 150	*150 to 249*	*250 or over*
Average yield per acre	122	180	301
Number of plantings	18	22	17
Acres strawberries per farm	4.7	3.3	3.3
Hours labor per acre			
First year	137	225	284
Second year, growing	13	53	16
harvesting & marketing	256	369	591
First year costs per acre			
Man labor	$ 67.78	$115.71	$141.47
Power and equipment use	34.58	22.26	53.02
Materials	78.14	93.87	90.79
Total	$180.50	$231.84	$285.28
Second year costs per acre			
Overhead items	15.44	50.69	82.15
Growing costs	26.32	49.81	30.71
Harvesting and marketing	181.37	270.34	414.34
Total	$223.13	$370.84	$527.20
Costs per crate of berries			
First year costs	1.47	1.29	0.94
Second year costs	1.83	2.06	1.75
Total	$ 3.30	$ 3.35	$ 2.69

Table 18

COSTS OF DEVELOPING AND PRODUCING AN ACRE OF STRAWBERRIES, BASED ON 57 PLANTINGS RANGING FROM 1–15 ACRES AND AVERAGING ABOUT 4 ACRES. MICHIGAN[531]

	Hours	*Value*	*Cost per Crate (189 Crates per Acre)*
First Year			
Man labor			
Preparing land for planting	6.5		
Marking out and planting	15.7		
Applying fertilizer	5.1		
Cultivating	18.4		
Hoeing and removing blossoms	137.1		
Spraying	7.6		
Mulching	15.9		
Irrigating	2.4		
Total	208.7	$103.46	
Power and equipment use			
Tractor	10.7	$ 16.44	
Truck	N. A.	3.85	
Other equipment		4.26	
Horse work	42.0	10.62	
Total		$ 35.17	
Materials used			
Plants		$ 30.70	
Mulch		30.39	
Fertilizer	N. A.	22.56	
Spray Material	N. A.	3.19	
Total		$ 86.84	
Total first year cost		$225.47	
Second Year			
Overhead costs			
Share of general farm expenses, interest and building use		$ 23.95	$0.13
Taxes		4.82	.05
Management charge		16.18	.08
Total		$ 44.95	$0.24

Table 18 (Continued)

	Hours	*Value*	*Cost per Crate (189 Crates per Acre)*
Growing costs			
Man labor	27.7	$ 13.60	$0.10
Power and equipment use			
Tractor	2.2	$ 2.39	$0.01
Truck	N. A.	3.35	.02
Other equipment		.91	.00
Horse work		2.94	.02
Total		9.59	.05
Total growing costs		$ 35.52	$0.19
Materials used			
Fertilizer	N. A.	$ 9.28	$0.05
Spray material	N. A.	3.05	.01
Total		$ 12.33	$1.06
Harvesting and marketing			
Picking labor	299.5	$155.63	$0.82
Packing labor	44.7	23.25	.13
Marketing labor	34.0	17.68	.09
Truck use		11.91	.06
Packages		64.24	.34
Total		$272.71	$1.44
Total second year cost		$353.18	$1.87
Total first and second year costs		$578.65	$3.07

some other purpose should be considered, as well as the disadvantages mentioned in the previous paragraph. (See also *Renewing Beds.*)

On the Pacific Coast, some long-lived, hill-system plantings occur.

Average yields of strawberries are far below possibilities. With a good site, proper culture, and suitable varieties, yields of 3,200 quarts up to 10,000 quarts or more per acre may be secured in favorable seasons. A quart of berries per foot of matted row is not unusual for the total picking in a good year, but in many plantings the yield is about half this amount.

Certainly many strawberry growers, without increasing their acreage, could more than double their present yield by judicious selection of varie-

ties and better culture. It is quite possible, however, to apply so much labor and materials to the crop in order to get higher yields that the cost per crate is greater than that for growers securing more moderate yields.

PROPAGATION OF STRAWBERRIES

General Considerations

Strawberry growers frequently are confronted with the problem of whether to propagate their own plants or buy them. In many cases the former is the best plan. The majority, however, seem to find it better to buy plants, as indicated by the extensive nursery trade. Probably more plants of the strawberry are sold each year than of any other fruit.

Nurserymen are experienced in preparing plants for shipment; sometimes, though, shipments are delayed for various reasons and the plants are damaged by heating and other causes. There are instances of diseases and insects having been introduced from one section to another on shipped plants. For this and other reasons, most, if not all, states require inspection of all plants sold.

When strawberry plants are grown solely for propagation, the usual practice is to dig the entire rows. When digging plants from a fruiting or prospective fruiting bed, they are usually taken from the edges of the row. Digging the entire row and discarding the old and the small plants undoubtedly furnish the best plants for setting. At times, propagating plants is a profitable sideline to the sale of berries.

There is usually a rush of spring work at planting time. It is important that a supply of plants be conveniently at hand to avoid delay in planting. Conditions with some growers are such that they can afford the time to dig and clean their own plants; whereas others cannot. It is annoying to begin planting and then need to stop until more plants are dug and cleaned.

Propagation is accomplished by means of runner plants. The slender runner stems, in contact with soil in suitable conditions, take root at a node (commonly the third node) and form new plants.

Plants well cleaned, with evenly bunched, straight roots, make setting easier, quicker, and better. It is often difficult to grow high quality plants in heavy, hard soil. Plants on soil which is naturally rich in humus or to which organic fertilizer is applied produce more runners than do plants treated with chemical fertilizer. The effect of nitrogen fertilizer, such as sulfate of ammonia, is to increase the size rather than the number of plants.

A large strawberry nursery firm in Maryland[157] states that in their experience bone and fish meal are helpful but nitrate of soda is injurious in stimulating plant production. Irrigation encourages prolific plant production.

Spring Planting and Rate of Increase

For spring planting, parent plants that have not fruited are set one spring and the new plants are dug the next spring. The following is an average rate of increase from parent plants in Ohio: Dunlap, 20; Aroma, 16; Gibson, 15; Sample, 14; Premier, 10; Chesapeake, 6. Ratios, of course, vary greatly; sometimes, for example, 50 new plants are obtained from each parent plant of Dunlap. In plantings solely for propagation, more than 100,000 plants per acre should be obtained, though such an estimate is influenced by many factors. The usual range is 75,000 to 150,000 per acre.

The following data were obtained in Ohio[106] on runner formation of Premier in a year characterized by drought periods during parts of May, August, September, and October and by abundant moisture during April, June, and July. Records were kept of 37,252 runners. Of this total, 387 runners, or 1 per cent, rooted in June; 6,568, or 17.6 per cent, in July; 10,310, or 27.6 per cent, in August; 2,602, or 6.8 per cent, between September 1 and October 15; and 17,384, or 46.6 per cent, formed, but only a small part rooted after October 15. Though the number of runners rooting in June was small, there is a correlation between those rooted earliest, or in June, and later totals and ratios, Table 19. A row of 15 plants in which only one runner had rooted in June produced 152 offspring (rooted) up to October 15, or 10 rooted runners from each parent plant. In a row with 12 plants rooted in June, the figures are 274 for October 15 and a ratio of 18 to 1; that is, the more plants that rooted in June the more runners there were per year. June is the date of earliest rooting of runners in Ohio. These data serve to emphasize the importance of getting the plants off to a good start; early planting, well-prepared soil, and good plants are very important.

Fall-bearing varieties are usually "shy plant producers." Fruit buds often form in leaf-axils in place of runners. This may occur on runner plants that have not yet rooted, and such runner plants may develop as many as three inflorescences and bring fruit to maturity without having rooted. Sometimes all buds on a runner plant, or all except those in the

axils of the first leaves, become flower buds. When all buds develop into inflorescences or runners, there can be no further development of the plant unless an adventitious bud is produced.

Winter Storage of Plants. Winter storage of perennial plants has been practiced by nurserymen for many years. The winter storage of strawberry plants, however, is a more recent development. In 1934, a Minnesota nursery successfully stored more than 300,000 plants of Dunlap, Dorsett, and Fairfax.[71] The bunched plants were packed in layers in orange crates, with the tops toward the sides of the crates. Sphagnum moss, shingle-tow, or peat was packed around the roots and between the layers of bunches,

Table 19

Earliest Rooting Runners in Relation to Rate of Increase of Plants. Premier. Ohio[406]

Number of Runners Rooted per 15-Plant Row			*Runners per Parent Plant*	
Earliest, or those rooting in June	*Total*		*October 15*	*Season**
	October 15	*Season**		
1	152	328	10	22
3	172	358	11	24
5	227	397	15	26
7	238	403	16	27
9	255	418	17	28
12	274	427	18	29

* These columns include runners which did not root after October 15.

but so far as possible the leaves were not covered. The crates were stacked with boards separating each tier so as to provide good air circulation. The air temperature in the storage shed was kept close to 22° F., and to prevent drying of the plants the humidity was kept high by sprinkling the floor at intervals.

Some advantages for winter storage are: winter injury can be avoided if the plants are stored properly; shipments of nursery stock can be made much earlier than is possible with spring-dug plants; nursery orders can be booked with the same degree of assurance as for other nursery stock in storage; the labor problem is simplified as fall digging removes this item from the rush of spring work in the nursery; with stored plants available

there is no danger of delayed planting because of conditions unfavorable for digging; and, the slight extra cost of handling is good insurance for the grower. Heavy losses may occur in northern regions if mulching is done very early so that the ground will not freeze to interfere with digging, and the mulch is removed and the plants dug during freezing weather in the fall. Under such conditions the plants may not harden under the mulch and may be severely injured or killed by freezing after digging and in storage.

In Maryland, Premier plants obtained from nurseries at different times throughout the winter were stored in crates with the roots in sphagnum moss. At the height of planting time in March, some plants of each lot were set in the field for comparison with freshly dug material. Most of the plants stored for three months at 17° F. were dead, but all other lots gave excellent stands. Of the several temperatures employed (17°, 30°, 32°, and 36°), 32° seemed best. Plants stored at 32° for as long as six months grew satisfactorily. The removal of leaves from plants at the time of storing was harmful, but when done just prior to planting proved uninjurious. In plantings made in late April or early May, under less favorable conditions, the plants from storage made consistently and often markedly better growth than did the checks, as indicated by leaf and runner counts and percentage of stand.

Though satisfactory results are obtained when plants are stored in crates, success also results from heeling-in. This method of storage is suitable when somewhat protected, well-drained sites are selected, and the plants kept heavily mulched through a cold winter.

Summer and Fall Planting

Where the Strawberry Is Grown as an Annual. In southern regions, as in Florida and the Gulf Coast region, where the strawberry is grown as an annual, the following procedure is commonly followed: (a) Plants are obtained during January, February, March, or April, mainly from Arkansas and Maryland, and are set out. This fresh stock serves a purpose, among others, of avoiding nema and certain other troubles. The plants start growth soon after planting and usually bloom and fruit before forming runners. If the flowerstalks are removed, runners will form sooner. The plant beds are kept free from weeds and given frequent shal-

low cultivation before the runners become too numerous, so as to reduce the work later. (b) In June or July, runners are taken from the parents, are planted in other beds, and, in turn, produce daughter plants. (c) These daughter plants are used for planting from September until mid-December. Under favorable conditions, 1,000 nursery plants produce 30,000 to 50,000 plants for fall setting.

Spring setting of plants in Florida is sometimes done fairly late (late March through April), and wider apart than usual (in rows 4–5 × 6 feet). No resetting is made in June or July, but the plants are maintained on the original beds until September or October when runner plants are removed and set for fruiting. This method eliminates the June or July reset which, in most years, is hazardous, owing to spells of hot, dry weather. This practice, however, is not as satisfactory as the one previously mentioned, and the number of plants that must be brought from the North for the original planting is larger than is necessary when the transplanting is done in June. Moreover, the June resets will have larger crowns and will bear better than those brought from the North in October or November and set at once to fruit the next winter.

In the Southwest Texas area the recommended practice[3,65] on sandy soils is to set plants in October, 10–12 inches apart, on low ridges 3–4 inches high and 18–20 inches apart, requiring about 30,000 plants per acre. On heavier soils double rows are sometimes used, plants being set 12 inches apart each way. These plantings begin to bear as early as December and continue until May unless severe frost intervenes. Heaviest production is usually in March and April. Plants are produced in the summer from portions of the bearing acreage reserved for the purpose. An acre of parent plants produces enough runner plants to set 10 acres in the fall. The problem of high temperatures in the summer is met by the use of heat-resistant varieties and other means of reducing heat damage such as frequent furrow irrigation, sometimes as often as every third day during the hottest periods.

SUGGESTIONS FOR THE SOUTH. Practices suggested for various southern districts are as follows:[164] Norfolk and Mt. Olive (N. C.)—Secure plants in February and March from the North or from local fields known to be free from nemas. Use them to set permanent fields. Chadbourn—Follow the above practice or set plants in February or March and raise plants to be set in the crop planting in August or September. Alabama and Mississippi (except Bay St. Louis, Miss.)—Follow the suggestions for the Norfolk

district. Hammond and Bay St. Louis (Miss.)—Follow either of these methods: (a) January or February—Set mother plants from the North. June 15 to July 15—Use the best of the runner plants to set a new planting for making plants. October to December—Use the best of the runner plants from the field set in June or July to set the crop planting. Houston (Texas)—December to March—Secure plants from the North in sufficient quantity and set the crop planting. Tyler (Texas)—February to April—Follow the practice advised for the Norfolk district.

Pot Method. Strawberries are propagated in pots to a limited extent for summer and fall planting in northern regions. Fruit can be obtained the next year, but the method is expensive. Potted strawberry plants are produced to supply a demand for plants that can be transplanted in the summer when extra care and skill are required to do this work successfully. The common method is to fill two-inch pots with loamy soil, sink them to the rim alongside the runners to be potted and place a tip in the center of each. In favorable weather the pots will be filled with roots in two weeks.

Crown Division. Even under favorable conditions few or none of the good fall-bearing strawberry varieties are prolific runner-plant producers. This condition may be expected because the buds that form in the leaf axils develop into either runners or flower clusters, and occasionally into branch crowns. Varieties producing many flower clusters in the summer produce few runners. For these reasons some method of propagation other than by runner plants is often desirable. The crown division method is rather simple and good results are secured if reasonable care is taken. Vigorous fall-bearing strawberry plants that produce few runners usually develop into plants with several crowns by winter. Not uncommonly some varieties produce 10–15 strong crowns per plant. Plants from which planting stock is to be made generally should not be more than one year old nor have produced fruit for more than one year. Older plants may be used but not as successfully as younger stock. Plants may be divided[58] either by breaking the crowns apart with the hands or by cutting them apart. Usually it is best first to cut the plant in two equal parts for a better view of the crowns and their roots. Each individual crown should be cut or broken off so that a number of roots are left attached to the crown, the more roots left the better, though where care is taken in handling and planting, plants with 5–10 roots may be satisfactory. Only the larger crowns that are $\frac{1}{2}$ inch or more in diameter and at least $\frac{1}{2}$ inch long should be used.

Location and Site

The large production of the chief market acreages of strawberries is disposed of through carlot shipments. Trucking has increased greatly. In some sections processing of the berries is a main market outlet. Nearness to market is an advantage, and locally grown berries are held in highest esteem. Low-priced land is an item of economy. Such a factor as availability of straw for mulching might not seem to be of much importance; yet in some sections the difficulty of obtaining straw and its relatively high cost are serious drawbacks. Though a good site is not a guarantee of success, continued success is seldom obtained without it.

It is usually better not to undertake a large acreage until experience has been gained from smaller plantings. Profits do not always increase in proportion to increased acreage. With regard to carlot shipments, to load a car daily a minimum of 75–100 acres conveniently located about the shipping point is necessary.

A level site is satisfactory if both the subsoil and surface soil are well drained. A 2 to 3 per cent slope is preferred, because it makes adequate water and air drainage more likely. If the site is very steep, there may be erosion, since the plants are cultivated intensively during the first year. When it seems necessary to grow strawberries on a slope that is likely to wash, the plants should be set out on a contour with the slope of the land.

For early market berries, a southern slope is best; but there is more danger of a frost, since plants on a southern slope start growth early and are more developed at the time of a late frost. A northern or eastern slope is safer from frost and should be used when possible for the midseason crop. The late varieties can be grown on the northern slope or even in the lower regions sometimes, since they usually bloom late and are, hence, not so subject to frost. In Northern Michigan,[203] a northern slope retarded the ripening of Dunlap by about nine days. Use of a clay loam on the north slope retarded the ripening date an additional four days over a sandy loam on the same slope.

Soil and Root System

Much of the discussion of soil, drainage, and other factors of site for grapes also applies to strawberries and so need not be repeated. Best success is obtained on relatively light soils, though certain varieties such as Aroma thrive well on heavy clay soils as in the Ozark region. The straw-

berry planting lasts only a few years. There is an important relation between reasonably light soils and the ability of the runners to root freely and to establish a good stand of plants quickly.

Since the roots spread out close to the surface and do not penetrate very deeply, the soil should be reasonably rich in organic matter in order to absorb and retain moisture well. Occasionally, soils are so rich that excessive growth is made at the expense of yield. Everbearing varieties seem to do best on a soil that is naturally richer than is suitable for most other varieties.

The fibrous root system arises from the short, thick stems near the soil surface.[306] Just underneath the surface, horizontal roots extend about a foot on all sides of the base of the plant. This limits the lateral spread. The surface foot of soil is fully ramified by obliquely descending roots, as well as many more or less vertically descending ones. The latter, especially, also ramify the second, and some of them the third, foot of soil. Branches are mostly short but abundant, usually being more profuse in the surface 12 inches.

There is some relation between top and root development.[309] Varieties with poor top development usually have poor to fair root systems. The root systems may be poor owing to shallowness, limited spread, large percentage of dead roots, dead tips, lack of branching and root hairs, and lack of thrifty roots, as indicated by the light color.

In the crown the entire vascular cylinder is made up of a network of short, anastomosing bundles which provide an efficient means of rapid transfer of water and solutes across the stem.[312] Moreover, these bundles themselves, instead of being made up of long vessels, are composed of short trachids provided with numerous, large, lateral and terminal pores which further increase the efficiency of cross, as well as longitudinal, transfer of water. Such a crown structure makes it possible for plants that have had most of their roots cut by a hoe or insect or destroyed by fungi to supply all leaves, runners, and other parts uniformly, in striking contrast to most woody plants. Reduction of any part of the root system affects the whole plant, rather than one side alone. Marked differences in the arrangement, development, and structure of the vascular tissues of the large adventive roots that arise from the crown, as compared with the small fibrous ones, together with the paucity of root hairs, account for their comparative inefficiency as absorbing organs. This apparently explains the difficulty in transplanting plants that possess many large roots, but no fibrous ones, as compared with those having at least a few small roots.

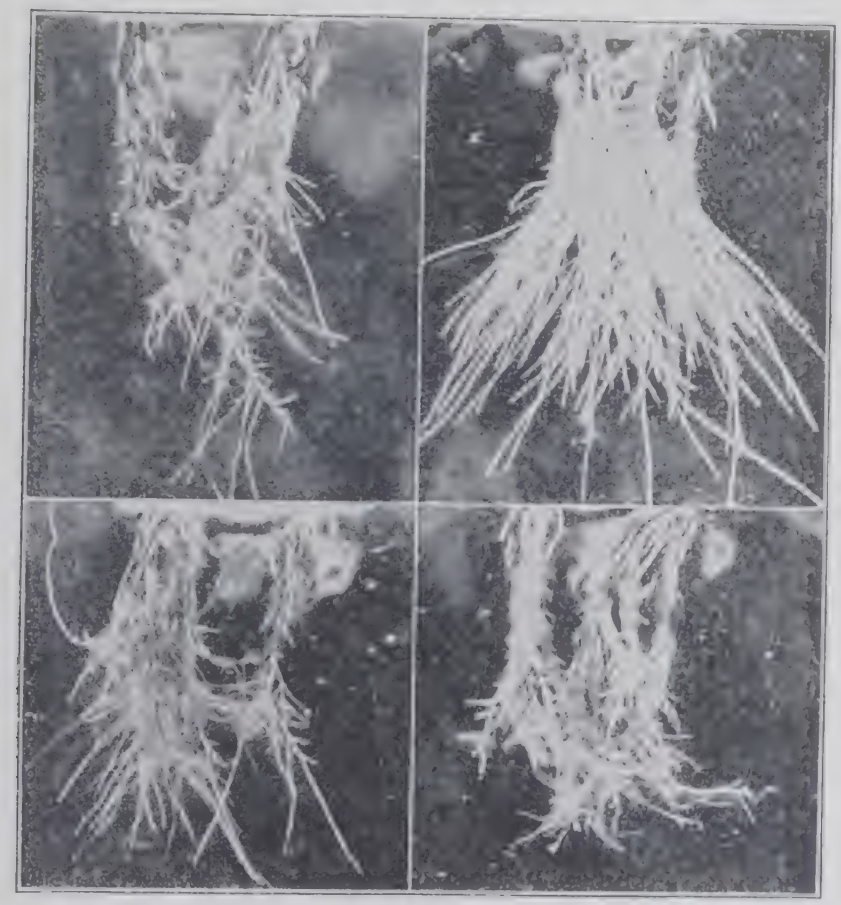
The moisture requirement of the strawberry is influenced by the fact that the root system is shallow and not extensive. In England,[27] 90 per cent of the total root system of the strawberry plant, based on dry weight determinations and expressed as percentages of the total dry weight of the root system, was present in the uppermost six inches of the soil; in fact, 75 per cent was in the first three inches.

Soil Reaction

The strawberry is not particularly sensitive to soil reactions, although it thrives best on a slightly acid soil.

In a Michigan[333] study: (a) Both wild and cultivated plants were found growing vigorously on acid, neutral, and alkaline soils. In most cases, however, the soils were somewhat acid in reaction. (b) In water cultures, plants survived within the pH range of 4–8. Growth was very satisfactory within the range of 5–7. The optimum reaction was 5.7–6. (c) The reactions commonly found in so-called "agricultural soils" are probably of themselves not important limiting factors in strawberry production.

A pH range of 5.8–6.5 seemed most desirable for the strawberry in



(Top, left) Strawberry roots grown in pH 7.5 solution. *(Top, right)* pH 5.7 solution. Note the superior root development. *(Bottom, left)* pH 6.4 solution. *(Bottom, right)* pH 4.4 solution. (Courtesy, J. W. Crist, Michigan Agricultural College.)

North Carolina,[293] with some indication that ammonium sulfate was more favorable on neutral or slightly acid soils and sodium nitrate on very acid soils. Studies with the Mastodon everbearing variety in Kentucky[294] showed the best response at pH 5.3–5.5. Acidity at pH 4 was more harmful to the plants than was alkalinity at pH 8.

The response at different soil reactions may vary with the form in which nitrogen is applied.* An experiment was started in New Jersey in October, in which Howard 17 (Premier), 16 plants per treatment, was grown for 56 days in pure, washed quartz sand. The nutrients were supplied in a solution continuously from an elevated reservoir, and their acidity ranged from pH 3.4 to pH 6.4 in steps of 0.6. Half the plants received their nitrogen as nitrate, and half received a solution containing nitrogen as ammonia. The nitrate series made good growth at pH 4.0, 4.6, 5.2, and 5.8; the best growth being made at pH 4.6; whereas the ammonia series made good growth at pH 5.8 and 6.4, with best growth at 6.4. Soil acidity is not the only limiting factor in securing satisfactory plant growth; consequently, these results secured in sand culture may not be applicable to the handling of all types of soils because of the variation in soil conditions including, among other variables, the existence of materials in the soil which may be toxic or which may in some way affect the utilization of the various forms of nitrogen.

Soils with a high-lime content in the upper 8–10 inches should be avoided in selecting land for strawberries. On such soils, which are rather common in the Snake River Valley, Idaho, and in the irrigated districts of Alberta and other areas in the west, strawberry plants become chlorotic (yellow leaved) and do not bear well. In some cases, there may be plenty of iron in the soil but it is not continuously available to the plants on the high-lime soils.

Liming is seldom necessary for strawberries. If an application is made it should be at least the year before planting strawberries.

Water Drainage

The strawberry does not thrive well on poorly drained soil. The effect of waterlogging is to reduce the root system, the old roots being killed and the new ones failing to develop to their full extent. Even on land that is tiled or with an open subsoil, winter thaws cause water to collect in low

* Courtesy J. H. Clark, New Jersey Experiment Station.

places, where it forms ice and may damage the plants. It is often a good plan to plow drainage furrows in the fall, before applying the mulch, to improve surface drainage and prevent water collecting about the plants during the winter and spring.

Since in most areas in the South Atlantic and Gulf Coast states the land is low and the drainage often poor, strawberry plants are commonly set in rows raised 3–12 inches above the furrows which separate them.

Climate and Weather Factors

Rest Period. Everbearing varieties are "long-day" plants, forming fruit buds under the long days of summer in northern regions. The more common varieties are "short-day" plants, forming their fruit buds chiefly when the days become short and the temperature low. Southern varieties grow under short days at relatively low-growing temperatures and need little rest or no dormant period. Northern varieties grow very little under short days, and, if first exposed to short daily light periods, require a low-temperature dormant period to break their rest. The rest period is caused by a short-day, low-temperature complex and is broken to a degree in some varieties by additional daily light exposures and in all varieties by temperatures at or below freezing. Missionary and Klondike are adapted to the South because they do not require a rest in winter but grow vigorously and form fruit buds during the short days of late fall, winter, and early spring, and can endure the hot southern summers.

Temperature. Studies at Glenn Dale, Md.,[19] on the relation of climate to the growth of the strawberry plant indicate that temperature is the chief limiting factor. High growth rates are maintained at daytime temperatures of 68° to 70° F. Above or below these points leaf production is decidedly lowered. A daytime temperature of about 73° is optimum. Average mature leaf size on spring-set plants attains a seasonal maximum in June, with subsequent decline in leaf size of plants that produce runners. A comparable rise and fall in leaf size occurs in runner plants. In Premier, the average length of life of leaves that unfold between April 1 and July 8 is 56 days, with a range of 21–77 days. Plants that produce runners increase gradually in total leaf production until about July 8, then there is a slight decrease. By July 8 the total leaf production of runner plants equals that of the mother and by August 20 is about seven times as great. Premier is very active and Aroma slow in leaf production. As measured by total leaf production, the vigor of the mother plant is greatly reduced by runner formation.

Spring Frosts. Because of the strawberry's habit of growing close to the ground where the coldest air settles, especially on clear, cold, calm nights in early spring, the blossoms are unusually subject to injury by late

spring frosts. Unmulched plants, plants on a southern exposure, and early blooming varieties are often the most susceptible. Mulched plants, on the other hand, bloom later and have more protection for their blossoms. Injury from late spring frosts is avoided to some extent by regulating the time of removing the mulch and by planting on a site with good air drainage. Rarely does total loss of the crop occur from frost. The blossoms of the strawberry do not all appear at once. The primary flowers, when uninjured, produce the largest fruits.

On a level area or one nearly level, a windbreak, by lifting what little wind there is, may cause a frost pocket behind it. It is not uncommon to see strawberry blossoms killed in the still air behind a windbreak while in the rest of the field they are uninjured.

Protection of strawberry plants usually is not necessary in Florida, but in some years much loss of income results from cold weather. A crop which requires as many months to grow as does the strawberry is well worth protecting from low temperatures which may stop the production for four weeks or more, usually while the fruit is commanding high prices. Three methods of frost protection are:

CYPRESS BOARD TROUGHS. Pecky cypress boards are nailed together to form V-shaped troughs which are inverted over the plants to protect them during cold spells. For this method single-row beds are best, these running east and west, so that when the troughs are in the uncovered position on the north edge of the bed they will not shade the plants.

Troughs are made by nailing together two boards of even length, one 1" × 10" and the other 1" × 12", this giving an outside dimension of 12 inches on one side and 11 inches on the other. A triangular brace is nailed in one end of each trough. Troughs of these dimensions will cover plants which spread up to 15 inches.

A total of 20,288 board feet of lumber is required per acre when the beds are spaced four feet apart. Of this total, 10,816 board feet of 1" × 12" and 9,021 board feet of 1" × 10" are required for the sides and 460 board feet of 1" × 10" for the braces. Cypress lasts for 10–15 years.

The advantages of this method are the complete protection afforded and the ease and speed with which the plants can be covered and uncovered. The heaviest labor requirement comes at the beginning of the season when the troughs are placed in the field and at the end of the season when they must be removed and stacked for storage.

PINE NEEDLES OR STRAW. This method is most widely used and is fairly good, but pine straw may be difficult to obtain. The straw is gathered in the woods, carried to the field and distributed in the alleys. It is raked onto the plants during the cold spells and carefully removed with the return of warm weather.

The disadvantages of this method as compared with the trough are that the protection is not so good, the process of covering and uncovering the plants is not so readily effected; hence, during prolonged cold spells plants may be left covered for several days, causing damage to plant and fruit, and a fire hazard is always present. Its chief advantage is the low cost of the material.

PAPER. Kraft wrapping paper is rolled over the bed and held in place by placing soil over the edges. The protection is fairly good but it is difficult to use the same paper for successive coverings and uncoverings. The cost of material per year is about equal to that of the troughs.

WIND. On the Eastern Shore of Maryland, severe northeast winds which prevail during late April and sometimes last several days dry out and wither the one-year-old plants, whipping them to the ground. Newly set plants often lose their leaves entirely, and their growth is checked. In sections where these winds are prevalent, the sites selected are protected by pine woods which act as windbreaks. When bordered by pine woods on the north side and exposed on the south, the berries ripen earliest in the area extending 30–40 yards from the edge of the woods.

HEATING. Where heating to avoid frost is considered, mulch is a fire hazard. Many small fires are more effective than a few large ones in avoiding frost damage. Heat is more beneficial than smoke. Considering all the factors involved, only in occasional cases is heating profitable on strawberries.

ROTATIONS

Sod land is not generally desirable for strawberries, unless it is cropped for at least two years previous to planting. Sod, particularly on sandy soils, is often infested with white grubs and other insects that may damage plants and cause a poor stand. In southern regions, soil infested with nematodes or eelworm should be avoided.

Strawberries should not be grown continuously on the same soil. Some chief purposes of cropping systems are to grow legumes or green manure crops in a rotation to build up a moderate humus content and to precede strawberries with cultivated crops so as to reduce certain insects and diseases, control weeds and grass, and improve the physical condition of the soil. The best rotation depends on the previous soil treatment, the adaptability of various crops to the soil, the acreage, utilization of the crops in the rotation, ease of incorporating the vegetative growth with the soil, limitations of the growing season, and many other factors. In general, the length of time that other crops occupy the land in a rotation should at least equal that of strawberries. If a grower has plenty of land, longer intervals between strawberry plantings are desirable.

Clover for two years is popular with some growers who follow a defi-

nite rotation. The clover is followed by a cultivated crop, such as potatoes, corn, or tomatoes. When strawberries follow corn, loss from wireworms and from root lice has been reported in some regions; ordinarily corn is a good crop to precede strawberries. Cultivated crops harvested by late summer may be followed by an overwintering crop, which is turned under early in the spring. When corn precedes strawberries, a cover crop may be seeded between the rows at the last cultivation. Sometimes a small grain

Table 20

A 5-Year Cropping System. Missouri[474]

Year	*Field 1*	*Field 2*	*Field 3*	*Field 4*	*Field 5*
First	Corn	Oats and cowpeas	Young strawberries	Fruiting strawberries	Fruiting strawberries
Second	Oats and cowpeas	Young strawberries	Fruiting strawberries	Fruiting strawberries	Corn
Third	Young strawberries	Fruiting strawberries	Fruiting strawberries	Corn	Oats and cowpeas
Fourth	Fruiting strawberries	Fruiting strawberries	Corn	Oats and cowpeas	Young strawberries
Fifth	Fruiting strawberries	Corn	Oats and cowpeas	Young strawberries	Fruiting strawberries

crop is grown between the clover and the cultivated crop. Garden vegetables for two years, with liberal manuring, make a fairly good short rotation with strawberries.

In Kentucky, Tennessee, and other tobacco-growing states, this crop is a good one to precede strawberries because good land is usually selected there for the tobacco. In the South, many growers use this rotation: after strawberries, a nema-resistant soybean or cowpea is drilled in rows; after this is turned under or harvested, winter oats are sown. In the spring the

oats are plowed under or harvested, and soybeans or cowpeas sown again. After this crop is harvested or plowed under, strawberries are planted in the autumn. Strawberries succeed well after sweet potatoes but in some sections may suffer from rhizoctonia root rot after potatoes, tomatoes, garden beans, or beets. Experience in Ontario has been that turning under

Table 21

A Rotation Program for Strawberries
Washington[447]

Look along the top of the different columns and find the crop now on the land and then follow through with crops given in that column.

FS_1	FS_2	FS_3	F	C	Cc	GM	YS
FS_2	FS_3	F	C	Cc	Gm	YS	FS_1
FS_3	F	C	Cc	GM	YS	FS_1	FS_2
F	C	Cc	GM	YS	FS_1	FS_2	FS_3
C	Cc	GM	YS	FS_1	FS_2	FS_3	F
Cc	GM	YS	FS_1	FS_2	FS_3	F	C
GM	YS	FS_1	FS_2	FS_3	F	C	Cc
YS	FS_1	FS_2	FS_3	F	C	Cc	GM

YS—Young strawberries.
FS_1—Fruiting strawberries, first year.
FS_2—Fruiting strawberries, second year.
FS_3—Fruiting strawberries, third year.
F—Forage crops (oats and vetch, rye and vetch, etc.).
C—Cultivated crops (potatoes, corn, tomatoes, etc.).
Cc—Corn.
GM—Green manure crops (oats and vetch, rye and vetch, etc.).

one or more crops of soybeans previous to planting strawberries is beneficial in overcoming root rot.

Interplanting Strawberries in Orchards

Strawberries sometimes are planted as intercrops in young orchards. The advantages, especially for apple orchards, are: they furnish an income while the orchard is becoming established; they bear the year after planting and give cash return; and they occupy the land for only a few years.

The objections are: mice are sometimes harbored under the strawberry mulch and may attack the trees; fire is a hazard when straw is placed in an orchard; orchard operations are made more difficult; the strawberries may

retard the growth of the trees; the tillage requirements vary too greatly, for trees are cultivated in early spring but fruiting strawberries are not because of the mulch and trees should not be cultivated as late as strawberries.

Planting

Preparation of the Soil

The importance of thorough preparation to secure a well pulverized soil for strawberries needs emphasis. Efforts should be directed not only to preparing the soil well but to doing so in time for early planting.

Time of Planting

It is important to plant strawberries early in northern regions for these reasons: there is a greater moisture supply in the soil early in the spring, and this greatly aids the establishment of the new plants; the strawberry responds well to moderate to cool temperatures; and, early spring planting promotes the formation of highly productive runners. As a rule, early spring planting is one of the "prime secrets" in successful strawberry growing; yet, certain difficulties are sometimes encountered: some soils are made loose and friable with difficulty if worked when too wet; and, sometimes the soil is made ready for early planting, then adverse weather results or the shipment of plants is delayed, and the soil must again be fitted, entailing increased expense. Normally, the benefits from early planting greatly exceed the objections.

As a rule, there are two weeks or so of relatively cool, damp weather in late spring when planting may be done, if it has been neglected earlier. It is difficult, in northern regions, to secure a good stand with plants set after the "May" rains. Plants set out in dry hot weather have a poor chance of doing well.

The actual time of planting varies, of course, with the locality (see *Propagation*). Time of digging is associated with the control of the crown borer which is prevalent in some southern states. Early moving of the plants prevents the transfer of the crown borer eggs to the plants used for the new planting (see under Insects).

Ordinarily there is one year, usually the first fruiting year, in the life of a spring-set bed that may be regarded as a "peak" year. When plants are set in late summer, even those plants that do become established will produce low yields the next year since few productive runners will have

been formed. If plants are set in midsummer, so as to provide more time to become established before winter, adverse conditions (dry, hot weather) are likely to cause a poor stand. Potted plants may be used, but this is expensive.

When the object of fall planting in northern regions is not to hasten fruiting but to encourage an early start in the spring or to avoid rush of spring work, extra cultural care is necessary in overwintering the plants and in controlling weeds. When planted in the fall the plants make growth early in the spring; this encourages early formation and rooting of runners, the benefits of which are discussed elsewhere in the text. With fall-set plants, much heaving may occur, and this may result in a poor stand the next spring. The roots of many of the surviving plants may be injured, and the plants may be unable to withstand later adverse conditions as well as thriftier plants. If fall-set plants are mulched to prevent heaving, there is extra expense for the material and its application and its removal in the spring to permit cultivation and the rooting of runners.

The discussion on time of setting under *Propagation* refers mostly to southern regions (see also Spaced-plant Rows). In western Washington, and neighboring areas, where winter protection usually is not necessary, though spring planting usually is better, plants may be set successfully in the fall. They should be set early enough in the fall to permit them to become well established before winter sets in; the established plants are thus in place ready to start growth in the spring. Damage to the planting from soil erosion and weed growth often follows fall setting. With fall-set plantings, especially after an open winter, weeds become troublesome in the spring and their control is costly.

In irrigated parts of Idaho[159] where the winters are not severe, well-rooted plants can be set successfully almost any time during the growing season except in very hot weather. Though planting in early fall (late August or early September) is satisfactory in the warmer parts of the state, only spring planting should be practiced where the ground may freeze four inches or more deep. Fall planting is preferred by some growers because the plants are well established by spring and the burden of spring work is eased. The increase in growth and production of fall-set over spring-set plants usually is not great and does not always justify the extra expense involved in controlling weeds in late fall and early spring. For most parts of Idaho early spring planting is advised.

Choice of Plants

Good plants for spring setting are thrifty and of the previous year's growth, with a well-developed root system of fibrous, light-colored roots, few leaves, a plump crown, and are free from injurious insects and diseases. Old plants are not satisfactory. They may be recognized by the presence of dark brown roots and a thick neck.

*Planting Distance**

The spacing generally used for strawberries in matted rows in northern regions is $3\frac{1}{2}$ feet between the rows and $1\frac{1}{2}$ feet in the rows, requiring about 8,300 plants per acre. This spacing often can be modified to advantage. Some prefer four feet between rows, but few exceed this distance. Rows closer than three feet seldom are advisable for commercial plantings in northern regions. Instead of planting $1\frac{1}{2}$ feet apart in the row the distance may be increased up to $3\frac{1}{2}$ feet on good soils with sorts that are prolific plant makers or where cross-cultivation is a major factor, e.g., hill system; or it may be reduced, especially in small plantings, to from 12–15 inches on rather poor soils with varieties that are indifferent plant makers. Suggestions for spacing in the South are given elsewhere in the text.

Self-unfruitfulness in Strawberry Varieties

Certain varieties are imperfect, or pistillate, and require mating, or cross-pollination, in order to develop fruit. The stamens of such varieties are lacking or abortive. Varieties with perfect flowers do not require cross-pollination, or mating, Nicholas Longworth, who is mentioned in connection with the historical development of grapes and black raspberries, was the first to note self-unfruitfulness in some strawberry varieties and the need of planting pollinators.

In interplanting, a row of a perfect variety to every three or four rows of the imperfect is a good guide, though satisfactory yields are sometimes obtained with a ratio of 1 to 5 to 1 to 6. The closer the two types are interplanted, the less is the proportion of deformed berries. The strawberry flower contains many pistils and, if a high percentage is sterile, or not adequately pollinated, an irregular, poorly-shaped, "button" berry is likely to be produced.

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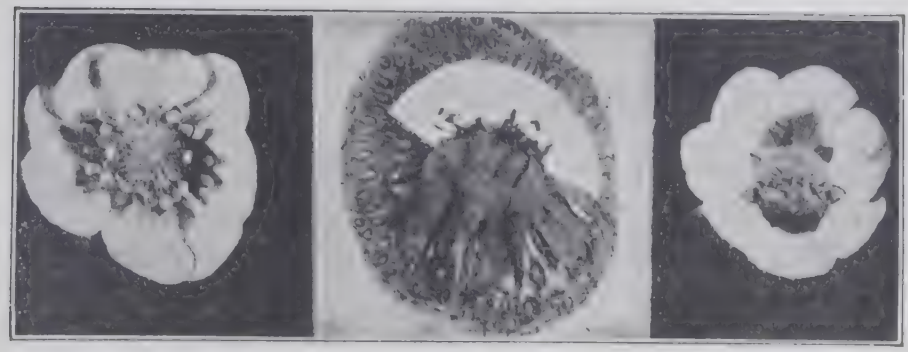
* See also under Systems of Training, p. 159.



(*Left*) Perfect blossoms. (*Right*) Imperfect blossoms. Perfect and imperfect varieties can be distinguished by fruits as well as by blossoms. (*Center*) Stamens are apparent in abundance underneath the sepals or "hull" of perfect varieties but are rudimentary or few with imperfect varieties.

Some perfect varieties are more effective as pollinators than are others. Also, adverse weather and certain other environmental conditions are detrimental to adequate cross-pollination. Not enough pollen may be brought to the pistils by insects or the wind. Bees which do excellent work in pollinating blooms do not work much in cool, wet weather. Or, the pollen supply may be poor as during very dry, hot weather when the pollen may be injured. Nubbins, of course, may also result because of injury to the blooms and young fruits by frost, cold, and winds. Imperfect varieties are less injured than are perfect ones by the strawberry weevil which feeds on the pollen. The planting of imperfect varieties involves the marketing of more than one variety, which may be a drawback.

In Ohio,[412] 76 rows of strawberries, 15 plants per row, were set out for several experiments in one bed. The spacing was $3\frac{1}{2} \times 1\frac{1}{2}$ feet. The first 20 rows were Sample, and the remainder Premier. The data, Table 22, clearly show a reduced yield of Sample with greater distance from Premier, on which it was dependent for pollen. The farther away from Premier, the more irregularly shaped and smaller were the Sample berries.

There is evidence[259] that the strawberry can set well almost without insects and that wind carries pollen to the flowers. However, some experience indicates that bees and other insects are important agencies in pollination and that their scarcity or inactivity during bloom is a drawback, especially with the imperfect varieties and during calm days.

A correlation exists between the flower position and fertility of pistils, fertility decreasing in the later flowers. Pistil sterility is expressed[413] by the production of irregularly shaped berries or entirely sterile flowers.

The size of berry is closely correlated with number of pistils per flower, and

in the setting of these pistils, there is a progressive decrease in number of pistils per flower from the earliest to the latest flowers to open. Early removal of primary, secondary, and tertiary flowers leads to increased setting of later blossoms but the resultant berries are small and the yield correspondingly reduced because of the smaller number of pistils per flower.[216]

The percentage of fertile flowers produced by a variety may vary with soil and season. The Ettersburg 121 variety in Oregon[972] is one of the most productive

Table 22

POLLINATION OF SAMPLE (IMP.) BY PREMIER (PER.) OHIO[412]

Proximity of Sample Rows to Premier (Rows)	*Yield of Sample for 15-foot Row (Quart)*
1–4	22.8
5–8	18.4
9–12	14.6
13–16	13.2
17–20	10.9

sorts on nearly all the heavy soils, but on lighter soils it is so sterile as to be unprofitable. On sandy soils in Maryland,[157] less than 1 per cent of the flowers of this variety set.

Heeling-in

See the discussion under grapes.

Marking the Rows

There are various methods of marking the rows the desired distance apart. A simple device for small areas consists of a handle, long enough so that a person can pull the marker without bending, and a cross-piece which enables three rows to be marked at once. Movable pegs then permit marking the desired spacing in the rows. In large plantings, usually a shallow furrow is made with a light plow. Long rows are preferable to short.

Setting Strawberry Plants

HANDLING THE PLANTS. For best results, the plants must be in good condition, not dried out nor heated in shipping or handling; the soil must be well prepared and well supplied with moisture; the crown must not be placed too shallow nor too deep with respect to the surface of the soil;

the soil must be packed firmly against the roots; and the roots must not be bunched too much in the soil.

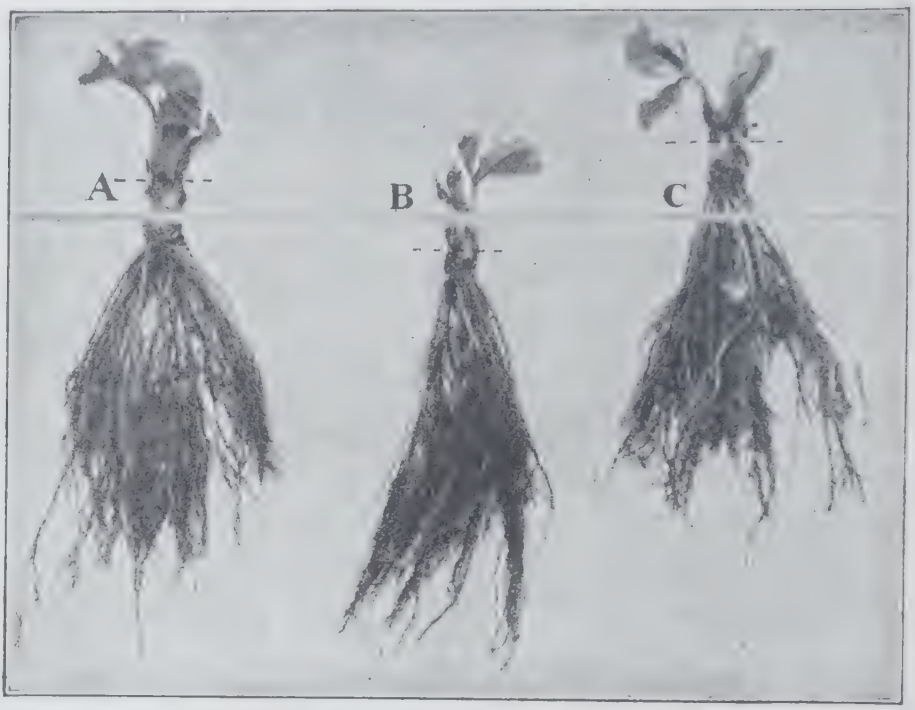
Exposure to wind or sun should be avoided. A good method is to take the plants to the field in baskets lined with damp moss and covered with wet burlap or other material. Another method is to immerse the roots in pails partly filled with water. It is important to drop only a few plants ahead of the planters, especially under drying conditions.

Trimming the Roots. Trimming the roots of strawberry plants one third to one half before planting did not impair or enhance their ultimate vigor in England.[27] The treatment resulted in the copious production of lateral roots near the cut ends of the main runner roots, and six weeks after planting the bulk of the roots equalled that of a "normal" plant. Root trimming may be best where the roots are very long and when a transplanter is used. With ordinary planting, little attention need be given to root trimming. Plants trimmed too close to the crown occasionally are damaged by cold soon after early planting.

Depth of Setting. The plants should be set at the same depth as they grew previously, or slightly deeper. When the crown is set too high or the soil is not adequately firmed, the plants are likely to dry out. When the crown is set too low, the plant may rot. As the plant develops, the short stems tend to become more and more above the soil.

In England[27] deep planting (just enough to cover the crown completely) caused some root death, but the ultimate vigor of the plants was not impaired. The increase in length of the main crown as compared with that of plants set at the normal depth was very noticeable. Shallow planting was more detrimental; it caused the death of some of the "primary" roots that were unable to reach the moist soil before succumbing to drought. The vigor of the plant the next year was also impaired.

Methods of Planting. In the spade method, two persons usually work together. One makes a V-shaped opening by shoving the spade (turned backward) fairly deep into the soil and pushing the top back and forth. The other worker then places a plant in position and holds it there while the spade is withdrawn and then used to press the soil against the roots on one side. Too much backward and forward movement of the spade should be avoided and care taken that no air space is left around the roots. The workers then firm the soil around the plant by foot. With very early planting, when the soil is not fully dried out, the soil need not be



Too shallow (A and C) and too deep planting (B); the broken lines indicate desirable depth. The plant tops and roots are suitably trimmed.

firmed quite so thoroughly around the plants as with later planting when the soil is drier.

When one man works alone, a trowel is a good planting tool. A worker exerting himself and with ready access to plants can set 5,000 to 6,000 plants per day.

A short-handled hoe is commonly used in Maryland.[512] By this method a man and a boy can set 8,000 to 10,000 plants in 10 hours. The boy carries the plants in a pail, keeping the roots moist, and drops them where they are to be set. The man carries a short-handled hoe in one hand and holds the plants up by the crown with the other hand, ready to make a short downward stroke with the hoe to open up a hole for the plant. This provides a hole with one side firm and smooth, and the plant is readily placed in position. Then, the planter, using the hoe, pushes the soil forward covering and pressing the soil around the roots with one quick motion.

Some claim that the furrow method is quicker and cheaper than the spade method; others claim that it is slower, more expensive, and less

reliable. The greater soil disturbance with the furrow method may lead to more drying out of the soil and less firmly set plants.

The horse-drawn transplanter is a quick method and waters the plants as they are set. Three men can set 20,000 to 25,000 plants, or 3–4 acres, in a day. One person drives the team and two others seated at the rear close to the ground place the plants in a trench made by the machine. The plants should be uniform in size, "stripped," and with the roots straightened out and arranged in one direction in the containers. Someone should follow the machine to tramp the soil about the roots, to straighten misplaced plants, and to fill the gaps. With careful and experienced workers, the transplanter gives good results. It is rather difficult with a machine to set the plants at the proper depth and to spread the roots as well as by hand.

SYSTEMS OF TRAINING STRAWBERRIES

Matted Rows

Most commercial fields in northern regions east of the Rocky Mountains are grown in matted rows. Runners are permitted to set in all directions. Cultivation tends to straighten the runners into the rows and to limit the width of the row.

The optimum width of row is influenced by such factors as variety, soil, and method of cultivation. Usually, a fruiting matted row of 15–20-inch width is preferable to a wider or narrower one. With equal planting distance, the wider the matted row, the greater is the yield. But, narrow to medium matted rows originally set $3\frac{1}{2}$ feet apart are likely to result in a more satisfactory product and are easier to pick than those set farther apart and permitted to become too wide. A point in favor of wide matted rows is that the runner plants can space themselves better in the row.

Best results are usually obtained when the plants finally stand six inches apart in the matted rows. With varieties and under conditions that produce dense foliage, spacing eight inches apart may be preferable. With varieties like Dunlap that make rather small plants, spacing four inches apart may be best. (See also Spaced-plant Rows.)

The aim should be to secure a full stand of plants in the matted row by early September in northern regions. It is a mistake to cut off early-formed runners; these are much more productive than late-formed ones (Table 26). With Premier, the need for thinning late runners may be less

imperative than with more prolific plant makers. With plants set late, it may be advisable to encourage rooting of late runners to secure a full stand. Late-formed runners are more subject than earlier ones to winter injury.

At Ottawa,[185] with Parsons Beauty, stolons formed in the early part of the season had the most stalks and hence the largest yield; though the stolons produced directly by the original plant were not in all cases the earliest formed or rooted, they gave larger returns than other stolons. Two plantings with an apparently equal stand of plants in November may give greatly different yields the next year if in one the stand is largely early-rooted plants and in the other is largely late-rooted ones. If a practically full stand can be obtained by the first of September (in northern regions), it is better from that date to keep the late-formed plants cut off, so as to give the earlier-formed ones every opportunity of developing crowns for the next year. Late planting should be avoided, where possible, as it is almost certain to result in low yield.

Hedgerows

Hedgerow training requires much careful work and entails definite placing of runners from each plant, after which all later plants are removed. In the single hedgerow system, the plants are set 15–18 inches apart in rows 24–30 inches apart. Usually two runners are permitted to root and these are bedded in line with the parent plants. Another hedgerow system is to bed 4–8 runners from each parent at nearly equal distances apart but restricted from extending too far between the rows. In general, in northern regions at least, the quality of the crop is improved but not in proportion to the cost.

Spaced-plant Rows

The Blakemore variety makes plants freely and the berries are small where the plants are too closely set and crowded. The plants at fruiting time should stand at least nine inches apart, considering maximum yields, largest berries, best grade of berries, least rot, greatest drought resistance, and greatest profit.[167] Twelve-inch spacing in double rows gives larger berries and less rot but not as high yield as does 24-inch spaced rows. Possibly double rows with plants nine inches apart and double rows $3\frac{1}{2}$ feet from center to center would result in yields nearly as large as from the

nine-inch spaced rows, with the fancy grade obtained from double rows as an extra advantage.

Blakemore runners are not quite so long as those of Missionary or Klondike, but are longer than those of Premier and are long enough for 10-inch spacing.

In Florida and southern Louisiana[157] where growth may continue throughout the year, the crop of Missionary and Klondike is produced by plants set in the preceding fall. If planting is done after a customary date (early October in central Florida), few runners are produced, even though growth is vigorous. Earlier-set plants, however, may produce runners. Some condition, such as length of day, or temperature, affects the plants in such a way as to inhibit runner formation on most plants set after this time in the fall. But, plants of these varieties in Florida when set in February may start forming runners in March and continue until the next fall.

Both single- and double-row methods of planting are used in Florida.[78] About 10–14 days before planting furrows are opened the proper distance apart and fertilizer is distributed in them. It should be well incorporated with the soil by means of a shovel-toothed cultivator or other suitable tool and so avoid direct contact with the strawberry roots at the time of planting. The bed is made up directly over the furrow, the height being dependent upon drainage conditions. Another method is to make up the beds without fertilizer, set the plants and make the first application of fertilizer after the plants are established and growing well. In the single-row method the beds are 36–40 inches from middle to middle, and in the double-row method, 48–60 inches. In the single-row beds, plants are set 10–14 inches apart in a single row on each bed, and so require 12,000 to 15,000 plants per acre. In the double-row beds, two rows of plants are set on each bed, the rows being 12–16 inches apart. The plants are spaced 10–14 inches apart in the row; the plants in the two rows are alternated rather than set opposite each other. The number of plants required per acre is 15,000–25,000.

In south and central Alabama, the narrow hedgerow is used.[252] The plants are set in rows about $3\frac{1}{2}$ feet apart. By fall a continuous hedgerow forms; it is kept narrow, not more than 4–6 inches wide. The prevailing opinion has been that 200,000–300,000 plants per acre are needed for good yields; but, in the hedgerow system, with 35,000–40,000 plants per acre,

the yield is as great as, and the quality superior to, that produced in matted rows.

Strawberries in Hills

In the hill system, all runners are removed as they appear and the original plants are encouraged to stool out in large crowns. Plants are

Because of their position on the cluster the earliest berries are usually the largest and the later berries smaller in size. The use of fertilizer cannot be expected to cause the berries which are at a disadvantage with respect to location on the cluster to become as normally large as the earliest ones.

spaced 12-30 inches apart in rows $2\frac{1}{2}$–4 feet apart, sometimes $2\frac{1}{2}$ feet each way to permit cross-cultivation. The hill system is commonly used west of the Rocky Mountains and in Europe. For propagation, "mother" plants are grown separately for the production of runners.

With this system in the far west, the berries are usually of superior size and quality and the picking season is relatively long. Plantings in hills can be kept clean easier than those in matted rows. Varieties incapable of developing large, multiple crowns are not adaptable to the hill system. Runners should be removed before they are 6-8 inches long when this

system is used. In sections where heaving may occur, the hill system is not suitable because each individual plant represents fruiting area equivalent in other systems to many plants.

Along the South Atlantic and Gulf Coast,[177] plants of Klondike and Missionary are commonly set in summer or fall and do not have any opportunity to make runners before fruiting. They are therefore grown under a hill system. In the irrigated regions of the West, nearly all varieties are grown in hills, e.g., Clark, Marshall, Magoon, Dollar, Ettersburg, and British Sovereign. In humid regions, varieties grown in hills are usually

Table 23

EFFECT OF REMOVING RUNNERS OF STRAWBERRY PLANTS GROWN IN 50-PLANT ROWS[157]

Row	*Removal Period*	*Average Number of*		
		Leaves	*Fruit Stalks*	*Fruits*
1	Weekly	23.50	3.54	18.32
2	Every 2 weeks	22.74	3.18	16.82
3	Every 3 weeks	22.78	3.34	17.20
4	Every 4 weeks	20.18	2.54	12.56
5	Every 5 weeks	19.40	2.10	12.36
6	Every 6 weeks	18.56	1.46	9.64

sorts that bear showy fruit of high quality or that make comparatively few runners, e.g., Chesapeake, Marshall, and Joe.

Strawberry plants in northern regions, except under very favorable weather conditions, seldom develop the large size necessary for successful hill culture as practiced in certain regions of the country where the climate, varieties, and other factors are suitable. In Indiana,[527] with 43 varieties, the matted-row plantings yielded nearly twice as much as hills.

The effect of removing runners is to decrease the average number of leaves, fruit stalks, and fruits, Table 23.

GROWING STRAWBERRIES IN BARRELS

For novelty purposes, strawberry plants may be set and fruited in barrels. Both heads of a heavy barrel are removed, holes are bored at 10–12-inch intervals in the sides, and the barrel is filled with fertile soil. The roots are inserted through the holes. The soil is kept level with the rows of holes until the plants are placed.

More soil is then added and firmed. A tile and sand cone extending upward through the center may be used to facilitate a proper moisture supply for the lower plants. Water is supplied at the top.

Removing the Flower Stalks

To insure strong fruitful plants when the proper time comes, all blossoms, flowerstems, and berries should be removed from newly set plants. This helps the plants to become well established by preventing a severe drain on their vitality from untimely fruiting, aids in overcoming drought conditions, and increases plant formation. In England,[27] deblossoming increased the general vigor of the plant in both root and shoot and reduced the damage from summer drought. Also, deflorating in the first year resulted in 6 per cent increase in plant diameter and 32 per cent in number of runners.[381] A test in Kentucky* with Premier showed that 98 per cent of the plants grew when the blossoms were removed at planting, in contrast with 83 per cent of those with blossoms left intact. The latter plants produced less than half as many runners as those with blossoms removed.

For varieties like Premier, which do not always make a desirable number of runners, the more frequently the planting is gone over the better it is for the plants. Varieties with an excessive plant-forming habit, like Dunlap, may not require much attention to blossom removal after the plants become firmly established. For such varieties, removing the flower stems once may suffice.

Blossoms of everbearing varieties should be removed for 60–80 days from planting and from then on should be allowed to form and develop into fruit. It takes about a month from blossom to ripe berry.

TILLAGE OF STRAWBERRIES

Cultivation soon after the plants are set and at frequent intervals thereafter controls weeds and grass and thus conserves moisture, improves the physical condition of the soil, prevents the surface of the soil from becoming crusted, and makes plant nutrients more available. Because of its low habit of growth, the strawberry is not able to compete as successfully as other fruits with weeds which deprive the plants of moisture, sunshine, and nutrients.

In Michigan,[309] an acre of strawberry plants producing 4,000 quarts of

* 44th Ann. Rpt. Kentucky Agr. Exp. Sta., p. 32, 1932.

fruit removed from the soil nearly three tons of water in the berries alone. Also, many times this amount was lost by transpiration from the plants and by evaporation from the soil. This emphasizes the necessity of an abundance of moisture during the few weeks between bloom and the ripening of the fruits.

In the first year, the plants should be cultivated increasingly shallow as the season progresses and farther from the original plants each time until the rows are of the desired width. In successive cultivations, always work the same rows in the same direction to avoid disturbing plants already trailed into position by the cultivator. A mellow soil encourages the rooting of runners.

Table 24

EFFECT OF FREQUENCY OF CULTIVATION ON YIELD. INDIANA[326]

Average Yield 24-quart Crates	*Average Number Cultivations*	
	Horse	*Hoe*
299	14.4	7.7
219	11.0	8.0
165	8.0	5.7
125	7.6	5.0
60	8.4	4.6

During the period of runner formation the soil should be kept well cultivated to encourage rooting. Pulling loose soil over the runners helps anchor them and hastens rooting. The later cultivations may ridge the soil slightly; moderate ridging helps to prevent water from standing around the plants, reduces winter injury to the crowns, and lessens loss from rotting of berries when rains occur during harvest. An important precaution in tillage is to avoid cutting close to the rows and then leaving an edge with roots exposed or poorly covered with soil.

In southern regions, cultivation ceases when the mulch is applied just before the blossoms open.

Hand hoeing is usually needed to keep weeds out of the row. At the first hoeing it is important to uncover the buds of too deeply set plants. Such plants when neglected are unlikely to be thrifty, even though they

live throughout the summer. The flowerstalks can also be removed at this time, though a separate practice of this work is usually best. At later hoeings, the runners are trained to vacant spaces, those that extend far between the rows removed, and crowded plants thinned. When rainfall is heavy, several hand weedings may be needed late in the first year or before picking the next year. The importance of weed control is aptly emphasized by the expression, "The best fertilizer for strawberries is a liberal application of sweat."

Frequent cultivation, when it is needed, is important in relation to high yields, Table 24. The number of cultivations is usually an index of the general care. Varying conditions will, of course, affect the optimum frequency.

After the first year, cultivation is usually delayed until after harvest. A good mulch is an effective substitute for cultivation in fruiting years.

2,4-D, slightly weaker than the usual strength of 1,000–1,250 p.p.m., applied after harvest, will control a number of weeds without seriously damaging the strawberry plants. 2,4-D does not control couch grass. ICC (iso-phenyl-carbonate) also offers promise as a weed killer and, in fact, there are a number of other materials that may prove even more useful.

IRRIGATION OF STRAWBERRIES

An adequate supply of moisture is basic. Timely irrigations in some years may increase or save the crop and improve the size and appearance of the berries. In other years little or no profit is derived from irrigation. It is particularly in years when non-irrigated plantings suffer most that irrigation gives best success. Usually the main purpose of irrigation is to supply water during the picking period. It is a good plan also to irrigate in the first year when the plants are not making good growth. For irrigation to be practical there should be an abundant supply of water near the field. To apply one inch of water to an acre requires 27,000 gallons.

Two methods of irrigation are: (a) *surface*—the water is delivered over the ground generally by furrows or flooding or from canvas hose, and (b) *sprinkler*—the water is delivered under pressure in pipes and is applied as a spray from perforated pipes or sprinkler heads. The sprinkler system may be permanent or movable. Growers often may construct a system which is practically as efficient as, and much cheaper than, elaborate overhead systems.

Surface Irrigation

Many growers use surface irrigation, made possible by their local conditions. The land should slope uniformly. When enough water is conveniently available, then, placing rows farther apart than usual, ridging the rows somewhat, providing a furrow in the center of the space between the rows, and employing surface irrigation in the evening, is often likely to prove profitable during the picking season. Cluttering up of the irrigation furrows by the mulch should be avoided as far as possible.

The rows for surface irrigation should not be more than 500 feet long, and preferably not over 300 feet, so that the water can run down the alleys without too much loss. During the planting and picking seasons water should be run down every other alley, so that the workers can walk in the unirrigated furrows. At the next irrigation the alleys previously omitted should be watered, thus alternating at each application. The water should not be allowed to touch the leaves under a bright sun, as foliage that is wet may "scald" and die. Wherever possible, the irrigated alleys should be cultivated in about two days after each irrigation, if the soil is in suitable condition for working and mulch does not prevent it.

In irrigated districts the plants usually are set on a raised bed, and water is applied in the furrow between beds as soon as planting is completed. If the soil is not well supplied with moisture at planting time, failure to apply water within a few hours after the plants are set may result in a poor stand.

In California,[248] the raised bed differs from level culture in that the plants are grown on a wide row slightly raised above the intervening spaces which are used for irrigating and cultivating and as paths for pickers. The sunken spaces in the raised beds are permanent during the life of the planting, whereas the furrows in level culture are made for each irrigation or at the beginning of the season. If lateral percolation is rapid and the entire bed is moistened quickly, the width of the raised bed may be greater than in soils where the water soaks in slowly. The common width of the raised bed and its adjacent furrow is 4–5 feet, the bed itself occupying more than half this width. The beds are raised 3–6 inches above the furrows and are 200–300 feet long. When the raised beds are too wide, there is difficulty in wetting the soil in the middle of the bed properly. In areas where the beds are narrow, the plants are set comparatively close in a single row in the center of each row bed. Runners spreading laterally are either cut off or moved to the center of the row, the rows being kept 10–12 inches wide. For wider beds and wider matted rows, the plants are set in a double row, the rows being 18–24 inches apart and 3–4 inches from the edge of the bed. A variation is to provide a rather narrow but deep furrow for irrigation extending the full length of the row in the

center of the bed. The paths, in this case, are not sunk below the beds but are kept on the same level. Raised beds can be watered more conveniently than level-culture plantings, as the ditches are permanent and are not destroyed by cultivation. Frequently, however, water is applied without any attempt to cultivate, and the result is a hard-baked path between the rows.

In Washington[191] the irrigation furrows are spaced close enough so that the water wets all the soil to the depth of root penetration. Some growers irrigate at 2–3 week intervals in early spring, gradually lessening the time elapsing until during harvest each picking is followed by an irrigation in every furrow or alternate furrow. After harvest the beds are irrigated frequently during the rest of the year.

The Corvallis variety produces most of its runners during July and August when, west of the Cascade Mountains in Oregon, rainfall is generally not sufficient to maintain adequate available soil moisture for normal plant functioning. Under such conditions, irrigations during July and August result in greatly increased production of runners. In a year with very little rainfall in September, irrigation in late summer greatly increases fruit yield in the next year. However, even with three summer irrigations, the best yields are obtained with between 14,000 and 32,000 well-spaced plants per acre, consisting either entirely of spring-set mother plants or of spring-set mother plants and of early-rooted runner plants, with excess runners removed. Since the three irrigations during summer greatly increase runner production, cost of cutting runners must be considered. If costs of keeping the plant population within the above limits are relatively high in proportion to yield and prices, it may be more profitable to irrigate only once in late summer.

In Colorado, on light soils during the bearing season, irrigation may be required every 4–6 days or even at shorter intervals. A common practice at harvest time is to irrigate between every other row so that there is dry ground between alternate rows for the pickers. At the next irrigation the alternate row-middles are watered. Irrigation is continued as necessary.

Where irrigation is practiced in Idaho, strawberries usually are planted on beds which are 4–8 inches above the furrows. During the first year, irrigation should be held to the minimum that keeps the plants in good vigor, as restricted irrigation encourages deeper root systems. During the fruiting period water is applied every 4–6 days on light soils and every 7–10 days on heavier soils, or alternate rows may be irrigated after each picking.

Though less frequent irrigation is required after harvest, the plants must not be allowed to suffer from lack of water at any time. Neglect in this matter may be reflected in greatly reduced yields in the next year.

Overhead Irrigation

The overhead system adds a uniform supply of water to the soil; it can be used on non-uniform soil or slopes; and it need not pack the soil. Since strawberries do not occupy the same land continuously, the use of this method is usually accompanied by intensive culture with vegetables. The strawberry can be rotated so that the cost of installation and operation is borne in part by other crops. Overhead irrigation often fits in nicely with intensive market garden systems of growing strawberries and vegetables.

The chief objection to the overhead method is that it is relatively expensive. Furthermore, considerable pressure is required for long lines. Once the overhead system is installed, it is fairly permanent, and its upkeep is relatively small. There are temporary overhead systems which can be put up and moved over the planting as needed. This type is less expensive to install.

The spray or overhead system can be turned on during periods of frost danger to afford some protection. If the temperature drops more than 2 or 3 degrees below the danger point, however, and stays down long, the flower-buds will be injured regardless of the sprinkling system.

For spray irrigation to be profitable, the crop should be increased in value at least $50 per acre.

Canvas Hose Irrigation

The porous canvas hose method allows the fruit and foliage to be kept dry during irrigation. It can be used well only where the slope is fairly uniform and where there is adequate water pressure, especially for rows more than 100 feet long. The hose is placed on the ground along each row, and water is turned into one end under pressure. The water oozes out through the canvas. As soon as the hose is filled with water, the pressure is regulated so that the soil absorbs the water as rapidly as it seeps out. When one row is well watered, the hose is moved to the next, and so on. Canvas hose can be secured from commercial firms, or it can be prepared at home from thick canvas duck. The canvas is treated with a preservative to lengthen its life, e.g., dipping the hose in a mixture of one

gallon paint and one pint each of gasoline and kerosene. After each year's use, it should be cleaned well and dried out to lengthen its life.

MULCHING AND WINTER PROTECTION

Merits and Objections

Occasionally winter weather conditions are such that unmulched plantings survive the winter as well as do mulched ones. One should not be misled by this occasional occurrence in the colder regions. Though mulching is not absolutely necessary, it is useful for a number of reasons. As a winter protection (in northern regions and especially on the heavier soils) it checks heaving of plants and damage to the roots caused by thawing and freezing. It also prevents the plants from drying out during the winter. In the spring and early summer it tends to prevent injury from frost by delaying bloom, keeps down weeds (provided it is free from weed seeds), conserves moisture, replaces cultivation, reduces the number of dirty and rot-infected berries, and makes picking more pleasant. Mulching also may improve the color of the fruit. Some objections are: the cost of the material; injurious effects from the use of improper material; difficulty and expense of obtaining suitable material in some cases; the possibility of weeds; in regions where the strawberry weevil or "clipper" is prevalent, the use of a mulch may result in injury to the blossom clusters; picking may be delayed somewhat; in the spring, there may be a sufficient difference in temperature to cause a frost on straw, while the unmulched portion may escape (this is probably due to the exclusion of sunshine from the soil during the day and to increased radiation at night). Sometimes when the plants are not mulched, as has been the case in some southern areas, the fruit is washed before shipment; however, washed berries do not ship well and washing is expensive.

The advantages of mulching usually far outweigh the objections. The practice of mulching in America dates back largely to the demonstrations of its value with the Jucunda variety about 1865 by John Knox, Pittsburgh, Pa. The name *strawberry* indicates that the use of straw in growing berries is a very old practice. In only a few regions, e.g., Southwest Texas, is mulching with straw or other material not practiced commercially.

Material

It is important to use mulching material that is free from weed seeds, does not pack down and cause smothering, is not too coarse or so light

that it blows away, and is not too expensive. Fine, chaffy straw is not desirable. In northern regions, clean wheat straw, or marsh hay, is usually the best material. Rye straw is fairly good. Cornstalks are too coarse for best results; oats and tree leaves pack down too much. Along the Atlantic Coast and in the South wheat straw is difficult to obtain and is expensive. In New Jersey, the common mulching material is salt hay cut from meadows near the coast. In the South, the chief mulching material is pine needles (these should be raked up and disposed of and not plowed under).

"We have rather an interesting situation in the state with reference to the use of cotton burrs for mulching. Most of the cotton gins have trouble disposing of cotton burrs. We have found that they make an excellent mulching material for strawberries. Coverage must be very light or the plants will be damaged during the wintertime; however, they do keep the berries clean and offer a cheap source of mulch. The chief problem is getting them spread. We have been doing some work with manure spreaders which looks quite encouraging and I think that we will be able to develop a system for the utilization of this otherwise waste material to the great advantage of the strawberry grower located adjacent to cotton producing areas."*

Later, in Oklahoma,[233] it is said that cotton burrs are a good mulching material. In the northern part of the state the mulch should be applied between December 1 and 15. In the southern part, where winter injury is not likely to occur, application may be delayed until later. When a bed is mulched after mid-December, only enough burrs should be applied over the row to control weeds between the plants and to keep the berries clean. The covering over the plants should be thin enough to permit foliage and blossoms to grow through, but thick enough between the rows (at least two inches) to control weeds and conserve moisture. After harvest the burrs can be worked into the soil without difficulty, thus improving the texture of the soil.

Sometimes, in northern regions, a cover crop of oats is sown in late summer or early fall between the rows and is allowed to mat down as it is killed by frost. Under some conditions the oats in dry periods take moisture from the plants and in wet periods grow so rank as to shade the plants and crowd their roots. The size of berries may be smaller than usual with this system. If a crop, such as oats, is grown for a mulch in a strawberry field, it is usually necessary to supplement it with a light covering of straw or other material.

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* Correspondence with Prof. F. B. Cross, Oklahoma A & M College, 1946.

A better plan is to grow suitable crops (in regions where strawstacks are not plentiful) solely for the purpose of producing mulching material. Even low spots, which are practically useless for fruiting strawberries, may produce a good crop of rye during the winter and early spring and a crop of Sudan grass after that in New Jersey. The kind of crop grown needs to be adapted to the particular region.

Use of paper as a mulch on strawberries is not satisfactory.

Mulching Practice

When a Winter Mulch Is Applied. The winter mulch is applied in the fall. No definite date can be set because the time of application should be governed by the temperature and previous exposure of the plants to frost rather than by the calendar.

Much of the injury in the field commonly attributed to "ice smothering" is due to lethal temperatures, excess water at the time the plants emerge from the dormant condition, or disease that may have had its inception in winter injury such as broken roots. The respiratory rate of dormant plants is relatively low during winter, and an ice seal maintained for 10 weeks or longer is not likely to cause serious injury.

The entire planting, both the plants and the space between the rows, is covered with clean wheat straw—the best practice for winter protection in northern regions.

Soil surface temperatures of 20° F. may cause injury.[419] Allowing the ground to freeze before applying the mulch, therefore, is not safe since much injury may already have occurred. But, subsequent resistance to cold is dependent on previous exposure to frosts at a temperature above 20° F. Too early mulching, therefore, may be as undesirable as too late. Mulch for winter should be applied only after the plants have been exposed to several frosts and growth has stopped, but before they have been exposed to lower than 20° F. Therefore, the ideal period for mulching may be rather short some years and may vary considerably from year to year.

If it seems likely that mice would cause serious damage, the best plan may then be to apply the mulch on top of the snow in the fall.

Table 25

YIELDS OF PLOTS MULCHED WITH CLEAN WHEAT STRAW, NO MULCH, AND WHEAT STRAW CONTAINING MANY WEED SEEDS. GIBSON. FIRST FRUITING YEAR. QUARTS PER PLOT. OHIO[406]

Treatment	*June*						*July*		*Total*
	19	*21*	*23*	*25*	*27*	*29*	*2*	*3*	
Clean wheat straw	0.9	5.1	12.0	18.5	20.0	19.0	31.0	12.5	119.0
No mulch	9.0	12.0	18.0	15.8	13.8	15.2	10.5	5.0	99.3
Weedy wheat straw	1.5	5.5	9.4	10.9	12.6	17.5	25.0	6.5	88.5

Dry, clean wheat straw is usually applied several inches deep, both over and between the rows. Four or five tons per acre of wheat straw make a good mulch in regions where strawstacks are available; where baled straw must be bought, the cost of the material is such that it may be advisable to reduce somewhat the amount applied. Too light an amount may seriously shorten the picking period and result in small-sized berries as well as in weakening of the root systems. Strawy manure sometimes gives good results, but it is likely to contain weed seeds and may not keep the fruit as clean as does wheat straw. If a field becomes very weedy, the yield is reduced and renewal for another crop is unlikely to be profitable. Baled straw, when used, should be thoroughly torn apart in the field several weeks before spreading over the planting; otherwise, a weedy condition may result. Another plan is to encourage weed-seed germination

(especially the wheat and cheat seeds) before applying the mulch, by partly tearing open the bale of material, wetting it, and exposing to the warmth of sunshine.

The berries from the no-mulch plot, Table 25, were dirty and brought a lower price than the mulched berries. The no-mulch plot led in early yield but was outyielded for the season by the clean wheat straw plot. Presence of seeds in the mulch reduced yield.

In the spring in northern regions, the mulch is raked off the plants and tramped down between the rows. Note the pipe irrigation system (water is pumped from a pond).

The winter mulch is usually removed in the spring after danger of frost is past but before there is appreciable "paling" of the leaves. If the covering is thin, the plants grow up through it, though some shaking of the straw may be desirable. If it is fairly heavy, however, it is best to rake most of it off the plants with a fork into the alleys between the rows, tramp it down, and leave it until after the picking season. It is customary to remove the mulch from propagation rows earlier than from fruiting rows. After the mulch is removed, weather conditions may make it advisable to cover the plants again for a short time. Where late ripening is

desired the mulch is left on the plants longer than usual. With this plan the plants sometimes become rather yellow before the mulch is lifted. This is not usually desirable, but it delays the picking season, and, in some cases, this may offset the slight setback due to the reduction in chlorophyll; of course, the matter should not be overdone.

When Winter Protection Is Not Provided. In the Gulf Coast region, in southern or other regions with mild winters, and to some extent on sandy soils in northern regions, the mulch is usually applied just before bloom. In the South, the time of application is usually delayed as long as possible to permit continued cultivation. The material is scattered over the beds, completely covering the plants which are later uncovered by hand. In Kentucky, the mulch is applied in late winter, six weeks or more before bloom. In British Columbia, where the hill system is used, long pliable oat straw is applied around and under the plants. About 30–40 bales of straw, or 1½–2 tons, are used per acre.

Under Irrigation. A straw mulch is somewhat more difficult to handle under irrigated conditions than on "dryland." But, a winter mulch for protection of the plants can easily be applied, or a fruiting mulch may be used in the spring after the first cultivation. The straw in such a case may be placed close around the plants, leaving open spaces between the rows for irrigation. It is feasible, under some conditions, to apply the fruiting mulch over the entire area between the rows if irrigation furrows have previously been established.

FRUIT-BUD FORMATION

Standard Varieties

In Northern Regions. Earliest studies of fruit-bud formation in the strawberry[232] showed that in 1899 it occurred in late September in the Clyde variety in Wisconsin.

In Iowa,[389] with Dunlap, differentiation began in early September but did not occur first at the corresponding time during each of four years. Furthermore, it extended over at least six weeks and did not occur in all plants at the same time. The early-set runners made the strongest plants and differentiated their buds first.[386] It seemed feasible to expend extra effort in getting an early set of runners and to thin out more of those plants which formed late in the season. The external factors of low temperature or lack of moisture taken separately or in combination proved

to be accompanied by a decrease in vegetative growth and was associated with the time of fruit-bud formation.[357] Fruit-bud initiation in Pennsylvania[163] was hastened by subjecting the plants to an eight-hour day. Runners subjected to total darkness after July 15 showed earlier initiation than did normal plants.

At Ottawa, Canada,[2,153,15] fruit-bud formation could be seen on September 19. Up to this date runners eight weeks from rooting differentiated no earlier than did younger ones.

From a survey of several varieties in areas from Massachusetts to Minnesota, it was concluded[157] that fruit-bud formation takes place during late September, occurring slightly in advance in the early varieties. In all sections fruit buds were visible to the unaided eye by mid-October.

There is not always a correlation between early differentiation of fruit buds, early bloom, and early ripening or between late differentiation, late bloom, and late ripening. However, for many varieties this correlation does exist.[493]

In Southern Regions. In the southeastern states,[175] fruit-bud formation in standard varieties is limited to autumn from Virginia northward. Apparently, the low temperatures of late fall and early winter stop fruit-bud formation, and when spring comes day length is too long. From Georgia to North Carolina shorter winters permit a resumption of fruit-bud formation in early spring before the day period has lengthened too greatly. At Willard, N. C. the initial stages of fruit-bud formation have been found as late as April 27. In Florida, strawberries evidently initiate fruit buds continuously during late fall, winter, and spring.

Sterility Factor. With Klondike, Aroma, Premier, Dunlap, and Missionary, the average was 60 per cent fruits and 28 per cent flowers not set for the plants rooted earliest, 58 per cent fruits and 32 per cent flowers not set for late July plants, and 51 per cent fruits and 41 per cent flowers not set for plants rooted in August and early September at Glenn Dale, Md.[156] This increase in unfruitful flowers could be attributed to the time of formation of fruit buds (the later-rooting plants forming fruit buds last) or to the relative vigor and food supply of the plants on which they were borne. If time of fruit-bud formation is the main factor, it would seem that the influence of one or more weather conditions effective during fruit-bud formation directly or indirectly determines the extent of sterility.

Fall-bearing Varieties

With fall-bearing varieties,[191] the fruit that ripens in May and early June develops from buds formed in previous fall, and the July crop is from fruit buds formed late in May and in June. Because of little or no differentiation in April, little or no fruit is produced in June and early July. Runner formation is high during this time but gradually becomes less, with fruit production increasing as the summer advances. The almost entire absence of developing flowerstalks over a period of 3–4 weeks immediately after the spring crop, together with the existence of favorable temperatures and long days, may be the cause of the unusual activity of everbearing strawberries in producing runners, new branches, and differentiating fruit buds all at this time.

After plants have fruited in summer in northern regions (standard varieties) they sometimes produce a light fall crop. The environmental conditions are such that flower buds form and open the same year. This is similar to the fall bloom which sometimes occurs in some shrubs and fruit trees; it is merely the formation of flowers when the chemical composition of the plant is suitable for it and the expansion of these flowers and the development into fruit when the environment is favorable.

Length of Fruit-development Period

About a month elapses from bloom until the fruit is ripe. An early first bloom is usually followed by a comparatively long fruit-development period but high temperatures during this period may shorten it to normal. The average length of the fruit-development period of various varieties differs somewhat, but a variety with a short development period is not necessarily an early one. Early-ripening varieties, however, are usually ones which bloom early, and late-ripening varieties ones which bloom late.

[191] At Wooster, Ohio, a heavy mulch of wheat straw (five tons per acre) was removed April 23, the plants started to bloom on May 11, were in full bloom on May 23, and the first picking was made on Premier on June 6. The winter was mild, severe spring frosts did not occur, and the "spring season" was somewhat later than usual. The dates just given refer to a Premier planting, bearing its first crop. Corresponding dates for an adjacent second-crop planting were: April 19, May 9, May 21 and June 5. Such time intervals are of some use in determining when to remove the mulch, and growers are advised to keep such records of their plantings from year to year.

FERTILIZERS FOR STRAWBERRIES

Fundamental Considerations

Conflicting experience on the value of chemical fertilizers is to be expected since conditions vary with different regions and years. The use of fertilizer is not, as is often assumed, a "cure-all." In northern regions, when the soil is reasonably fertile at the start: careful early planting in well-prepared soil, thrifty plants, proper variety, removal of flowerstalks, adequate moisture, the quantity and quality of the mulch, weed control, and a number of other factors are usually more important than is application of fertilizer. Later procedure may be inadequate to compensate for lack of a good early start for the plants. The northern grower, in particular, should give careful study to the matter of use of fertilizer because it will pay to apply it in some but not in all cases. In the South, where fertility is decidedly lacking, liberal application of fertilizer is necessary for maximum yield.

It seems logical in a discussion of the use of fertilizer to consider, first of all, the possible basic ways in which the yield may be increased or a high yield be made possible. These are (a) suitable variety, (b) a good stand of plants, (c) a high percentage of early-rooted runners, (d) an increase in the number or in stimulation of fruit buds, (e) an increase in the set of blossoms, (f) an increase in the size of the fruit, and (g) a long picking season. The second, third, and fourth points are concerned primarily with conditions during the growing season previous to fruiting, and the last three during the fruiting season (except in regions where the strawberry is grown as an annual).

Suitable Variety in Relation to the Use of Fertilizer. Certain varieties are inherently more productive than others. Providing other factors are not limiting, the use of fertilizer does not cause the yield of a comparatively low-yielding variety to equal that of a high-yielding one. In order to obtain a high yield it is necessary to select a variety which inherently possesses this characteristic.

The value of varieties depends largely on their growth habit.[177] One of the best types of growth for eastern states is that of Premier, which tends to produce irregular, low-branching flower clusters with relatively large berries. On a fertile soil its vigor is expressed in branch crowns and increased size of low-branching, irregular flower clusters that bear many large berries. In contrast, Missionary and Klondike on sandy soil near Washington, D. C., tend to produce small flower

clusters which are high-branching, and when their vigor is increased they tend to the growth habit represented by Premier.

The proper choice of variety for high yield depends on the region, the site, and various other factors, many of which are much more significant than the use of fertilizer.

STAND OF PLANTS IN RELATION TO THE USE OF FERTILIZER. On a given area the number of fruit trees set at a certain spacing is not subject to increase, but with the strawberry in the matted row it is, because of the runners. Early planting, well-prepared soil, careful planting, thrifty plants, proper variety, removal of flowerstalks, and a plentiful supply of moisture are important factors in a good stand of plants (both parents and runners) and are much more significant in this respect than is the use of fertilizer. That there is a correlation between the number of runners rooted earliest and the total number for the year has been previously indicated. Certainly, a plant of a given variety set, for example, in early April in northern Ohio will produce more runners for the year than will a corresponding plant set a month or more later. A primary consideration is to encourage the plants to a good start soon after planting. There is no proof that a fertilizer can make the yield from a given variety with a poor stand of plants as high as that from the same variety with a good stand.

A wide row of plants does not of itself insure a high yield. A greater number of comparatively narrow rows may more than compensate for wider rows planted farther apart. At the Ohio Station, the ends of the rows near a tall evergreen windbreak were wider, the plants taller, the foliage more dense, but the yield was consistently less and the fruit later than from the ends of the rows relatively distant from the windbreak. A number of other limitations to the advantages of wide rows might be mentioned, e.g., more plants demand more moisture and nutrients. It may be stated as an axiom, however, that a good stand of plants is necessary for a high yield. Use of fertilizers does not guarantee a good stand of plants nor does it fully compensate for the lack of a good stand.

In Arkansas[135] there was an increase in yield wherever there was an increase in stand up to eight plants per square foot on Newtonia soils and 10 plants per square foot on Ruston soils. But, as stand increased there was a decrease in yield per plant.

"Starter solutions" are often helpful in getting the plants away to a

good start but do not dispense with the need for early planting or other important factors which have been mentioned in this respect.

Early Runners in Relation to the Use of Fertilizer. Two rows of plants which have received the same fertilizer treatment and appear equal in stand may vary greatly in their yield, if in one of these rows most of the runners rooted early and in the other they rooted late. The variability in plants, e.g., in age of runner plants, is highly significant with respect to yield. That early-rooted runners are the most highly productive is shown by an Ohio experiment.[406] Twenty-five rows of Premier were selected for a comparison of yield from runners rooted in different months. Stakes for the runners rooted in each month, following planting in early

Table 26

Yield from Runners Rooted in Different Months the Previous Season. Premier. Ohio[406]

Runners Rooted, Time	*Number*	*Total Yield Year, 1929*	*Yield per Plant, Quart*
Parent plant	375	48.8	0.13
June	162	21.9	0.14
July	1,989	79.0	0.06
August	3,884	131.1	0.04
September–October 15*	1,127	13.9	0.01
October 16–November	3,375	23.2	0.009

* Decrease in number of runners rooting due to drought.

April, were painted a different color, and yields were recorded in the next year from the respective groups. Though there were, of course, more runners formed late than early, the yield was about 15 times as great for a runner rooted in June as for the one rooted in September or later.

As the yield from one plant rooted early is equal to that from about 15 plants rooted late, it is clear that fertilizer would indeed need to cause a marked response to help a late runner overcome its handicap. Since more runners are rooted late than early, a small increase per plant from a fertilizer may partly offset the higher yield value of the early runners. But, more significant is the viewpoint that weak runners, rooted late in the season, may be "weeds" using the soil moisture and nutrients that are needed by the earlier-formed plants to develop and mature their fruit buds and build up an adequate food reserve for fruit production.

Results in North Carolina[335] show advantages for practices that promote as many new plants as possible during June, July, and early August. Again, it would seem that the role of fertilizer is a secondary one. Runners were pegged down at 15-day intervals (June 2 to November 3). The plants rooting earliest were much more prolific than those rooting later, there being a marked decrease in flower and fruit production on the plants rooting after August 15. As the age of plant increased, the average number of flowers and berries from each group showed an increase in average berry size as the age of the plant decreased. The size of berry, therefore, was inversely proportional to the number of berries per plant. Any increase in percentage of flowers that formed fruits was associated with the number of flowers per plant, rather than with the age of the plant.

At Ottawa, Canada,[336] stolons formed as late as October 20 produced an average of only five fruits; those formed about mid-August produced 16 fruits. Though more than one third of the stolons was formed in October, they produced only 19.6 per cent of the crop. One fourth of the stolons was formed in August and produced 34 per cent of the crop. This shows the value of early planting and good care early in the year. When a heavy application of manure was made the year before planting and the land used for a hoed crop, there was on good soil enough nitrogen and other plant nutrients to encourage maximum runner formation early in the season.

In Iowa,[337] the mother and oldest daughter plants contained the largest carbohydrate reserves throughout the growing season and were the most highly productive. In New Hampshire,[338] Premier showed the highest average number of new plants on the stable manure plot, because of a greater branching of the runners. In plant size, all treatments gave much the same results; the first plant on a runner was the largest.

In England,[339] plants taken from parents allowed to produce only three offspring yielded more than progeny of plants with unrestricted runners. Early-set plants were more profitable owing to higher yield. Tests in New Jersey[340] of large and small Lupton plants for establishing new beds favored the larger plants in the number of new runners formed, and in yield.

Good advice for growers using the matted-row system is to encourage the formation, rooting, and development of early runners of good size. As stated earlier, a number of factors are highly influential in this respect; in fact, more so than fertilizer.

In spaced rows the thinned plants develop larger roots and crowns than they do in matted rows. Fertilizer applied in autumn increases the dry-matter content of the roots. The longer continuance of growth of plants in thinned rows, as well as response to fall fertilizers, contributes to a better crop, especially in areas where Blakemore is grown.

Number of Fruit Buds in Relation to the Use of Fertilizer. An increase in the number of fruit buds often means a larger plant. A number of experiments have shown increased yield and higher earlier pickings

from nitrogen, applied near the beginning of fruit-bud formation. Though an increase in the number of fruit buds is undoubtedly, in some years, an effect of fertilizer, other factors may be more significant in the average planting; e.g., with the same number of plants in two given rows, if in one of these rows the runners rooted early and in the other they rooted late, there would probably be more fruit buds per plant in the first row.

A large plant does not necessarily result in a high yield. Certain varieties make very large plants but produce comparatively low yields. Also, too vigorous growth may be at the expense of yield. This suggests that too much, as well as too little, fertilizer may adversely affect yield.

With Premier in quartz sand,[312] fruitfulness is correlated with a relation between nitrogenous and carbohydrate materials in the plant at the time of fruit-bud formation. A weekly vegetative type of growth and a reduction in the number of blossoms formed is associated with a high carbohydrate and low nitrogen content, or an abnormally high carbohydrate-nitrogen relation. A strongly vegetative type of growth and a reduction in number of blossoms formed is associated with a low carbohydrate and a high nitrogen content, or an abnormally low carbohydrate-nitrogen relation. On moderately nitrated plots a vegetative type of growth intermediate between that made by the plants on the high- and no-nitrogen plots is associated with a carbohydrate-nitrogen relation intermediate between that of the high- and no-nitrogen plots. Likewise, an increase in blossom formation on the moderately nitrated plots is associated with an intermediate carbohydrate-nitrogen relation.

In Michigan,[308] plants given nitrogen in the previous summer grew better in the spring of the fruiting year than the untreated or spring-treated (first-year) plants. When nitrogen was used in the spring of the crop year, the response in growth was greater in plants grown under poor nutrition the preceding summer and fall. Phosphorus alone did not affect growth. With nitrogen it promoted a larger growth and yield than did nitrogen alone. With a limited supply of nutrients in the soil the roots were larger in proportion to the tops; with a moderate supply the root system was less extensive and the tops proportionally larger. When phosphorus and potash were used with nitrogen the proportion of tops to roots was larger than from nitrogen alone. The total number of flowers per plant as modified by fertilizer was determined chiefly by the number of flowers per cluster. Nitrogen increased the number of flower clusters. Summer-treated plants produced nearly twice as many clusters as did spring-treated ones. Fertilizing in the spring of the crop year did not affect the number of clusters or flowers per cluster. The proportion of flowers that set was influenced by the nutritive conditions both in the plants the preceding fall and in the soil at bloom. Summer-treated plants containing more nitrogen at the end of growth in the fall set a larger percentage of blossoms than did spring-treated plants low in nitrogen. Use of nitrogen in the spring of the crop year caused a better set of blossoms and an increase in size of berry. Nitrogen alone or with phosphorus and potash increased yield. Yield was

higher from summer- than from spring-fertilized plants; largest yields occurred on plants fertilized in both spring and summer and again in spring of the crop year. Variations in the nitrogen content of the plants at the time of fruit-bud formation affected yield more than did variations in carbohydrate content. Low nitrogen was associated with low yields; high nitrogen, with high yields. Plants with both high nitrogen and high carbohydrate contents were most productive. Size of the crown was not an index to yield. Total yield was determined by number of flower clusters and number of blossoms that set and developed into fruits, and so chiefly by nutritive conditions in the plant at the time of fruit-bud formation during late summer and fall.

At Atmore, Alabama,[47] a January application of nitrogen increased the number of berries, the number of blossoms, the yield of No. 1 berries, and the number of very large berries. The increase in the number of berries resulted chiefly from an increase in the number of flowers produced rather than from a higher percentage setting fruit. Also, where nitrogen was applied in January or February of the fruiting year to well grown plants, there was usually an increase in the number of open flowers in about two months after treatment.[47b] Where the plants were weak when treated, an increase in the number of flowers was noted earlier, because of the opening of weak buds. Use of nitrogen fertilizer on nitrogen-deficient plants, just before harvest, tended to suppress flower and fruit production while leaf growth was most rapid. Used in the fall or early in the fruiting year, it did not supply sufficient, as indicated by foliage growth and soil nitrate content, over a long enough period to produce large yields. Generally, when nitrogen fertilizer is applied in the fall, more flowers bloom early and so are killed by cold than where it is withheld until January or February of the crop year. However, the plants fertilized in the fall and supplied with more nitrogen later produced a larger crop than otherwise. Apparently nitrogen should be used in the fall and again about 90 days prior to the average date of first harvest in order to insure production of a large number of flower clusters that are effective in producing the crop. A later application may also be advisable to ensure the production of berries of large average size.

In Ohio,[48b] sulfate of ammonia was used on Premier at rates of 50, 125, 250 and 500 pounds per acre and applied at planting, a month later, and August 15. Split applications were also used. The highest yield was obtained from 125 pounds a month after planting and another 125 pounds August 15, and all the applications increased yield. The late summer application is timely with respect to the time when many runners are forming. These late-formed runners are not so well developed as earlier-rooted ones, and stimulation from the fertilizer has increased the yield in some years. Fruit-bud formation for the next year's crop also becomes active about this time and the fertilizer seems to stimulate it. The application also seems to increase the top and root growth and sometimes earliness. An application of 250 pounds early in the spring of the fruiting year to vigorous plants resulted in a lower yield during the first half of the picking season but in a slightly higher yield during the later pickings and a smaller yield than from the untreated rows. The spring application promoted darker green foliage, an increased amount and density of foliage, comparatively slow picking, larger berries during the later part of the season, and more decay.

SET OF FRUIT IN RELATION TO THE USE OF FERTILIZER. Fertilizer, particularly on soils low in nitrogen, often increases the set of the blossoms and resulting fruits. It is questionable, however, whether an increase in set of a bloom on a fair to poor stand can adequately compensate for a normal set on a good stand of plants.

At Ottawa, Canada,[315] the total set of fruit was increased 5 per cent by a spring application of nitrogen fertilizer before bloom. The increase on the later bloom, such as the quartenary, or last-formed blossoms, ran as high as 26 per cent.

Summer use of fertilizer increased the number of flower clusters per plant in Missouri, but no treatment increased the number of blossoms per cluster. Spring use of 15-30-15 (400 pounds per acre) fertilizer greatly increased the number of flower clusters per plant. A 160-pound-per-acre application of 15-30-15 fertilizer in summer and again in spring caused more blossoms to form and more fruits to mature than did any other treatment.

In some cases in Ohio,[206] the use of a nitrogen fertilizer just before removing the mulch in the spring caused a vigorous growth of foliage which prevented frost-injury to the blossoms. In most cases it promotes excessive foliage development which brings about undesirable conditions.

SIZE OF FRUIT IN RELATION TO THE USE OF FERTILIZER. Plots in North Carolina[162] to which nitrogen was applied produced much larger berries than did those without nitrogen. Counts of 11–14 quarts from each plot showed 13 per cent larger berries in the nitrogen plots, because of greater swelling of the fruit.

Fertilizer, particularly nitrogen, increases the size of the fruit. The same may be said for careful spacing and for limiting the number of plants, for watering, and for a number of other factors. Fertilizer cannot be expected to make the berries from inherently small-fruited varieties as large as those from normally large-fruited sorts. Increased size of fruit may result in softer berries.

LENGTH OF PICKING SEASON IN RELATION TO THE USE OF FERTILIZER. Sulfate of ammonia, 250 pounds per acre, has made the "peak" of the picking season slightly later in Ohio,[406] just late enough to encounter low prices. The berries in the later part of the season were slightly larger than those from check plots. Irrigation tends to make the picking period longer than does the use of fertilizer, even more so than delaying the time of lifting the mulch and applying fertilizer.

GROWTH STATUS. The foregoing discussion emphasizes the fact that the response from fertilizer depends on the condition or growth status of

the plants as the chief factor. During a certain year the plants may respond to a given fertilizer in one way; whereas, the next year a similar response may be made to abundant rainfall without the addition of any fertilizer.

The strawberry is very sensitive to boron and under southwestern New Hampshire conditions[292] more than five pounds of this element or 25 pounds of borax per acre is injurious whether applied to the bearing or to the newly planted bed.

Humus in Relation to Fertilizer Considerations

That the organic matter content of the soil is a factor affecting strawberry yields is shown by a study of 63 southern Indiana plantings of Aroma.[326] The yields ranged from 47–380 24-quart crates. The 10 leading growers produced 252–380 crates per acre, averaging 299 crates. In preparing the soil for planting, four of the 10 growers plowed under an average of 19.5 loads of manure; two plowed down cover crops; two plowed under heavy sods of long standing and grew corn one year before planting to berries; one planted on new ground; and one plowed under manure prior to sowing wheat, which was turned under the next year. Of the five growers in the lowest yielding group, 47–68 crates per acre, one used 1½ loads of manure per acre in preparing the soil; two had plowed down cover crops, but two intensive crops preceding the strawberries had benefited by this before the berries had their chance; one plowed down orchard grass and was lucky that white grubs did not entirely destroy his planting. The growers in the lowest yielding group averaged 77 per cent less production than those in the highest group..

Studies in Kentucky* indicate that the method of application and rotations may be important in reducing the expense for fertilizer. The land was very poor, corn crops averaging only 15 bushels per acre; it was low in phosphorus and tested about pH 6. Four series of plots were given a uniform treatment of one ton of ground limestone and 400 pounds of superphosphate per acre. The berries were grown in a rotation with sweet clover. Nine crops were harvested from four series of plots (40 plots in all). In every case, extra fertilizer, either nitrate, phosphate, or potash reduced the yields below the checks, the greatest reduction in yield being from the application of nitrogen. The yield on the check plots ranged

* Correspondence with C. S. Waltman, University of Kentucky.

from 125–183 crates per acre. In this district, the practice has been to use 400–600 pounds of 4-12-4 fertilizer, and the growers have reported that they were pleased with the results. Some growers have used about 500 pounds of superphosphate and felt that they obtained excellent results, but the experimental results were fully equal to those of the better commercial growers, and the expense was far less. This seems to indicate that commercial practice, though apparently satisfactory to the growers, may be wasteful and expensive.

Soils well supplied with organic matter retain a relatively large supply of moisture which is available to the plants; whereas on soils low in organic matter the plants may be suffering from lack of moisture.

If two or more crops are to be harvested from the planting, a larger amount of organic matter in the soil is likely to be needed than for only one crop. The amount should not be excessive for the first crop and a comparatively slow rate of decomposition or availability is desirable providing this does not introduce certain adverse factors.

Suggestions for Fertilizing Strawberries

Northern Regions. Some suggestions are as follows: (a) Previous to planting, build up in the soil a moderate supply of decayed organic matter or humus by turning under a green manure crop, or well-rotted manure, and by the use of a good rotation. Subsequently, by following the good cultural methods which have been outlined, a need for fertilizer is the exception rather than the rule, unless the soil is markedly deficient in fertility. Where manure is not available, about six tons of hay or straw per acre with 300 pounds of nitrate of soda* (or its equivalent in other nitrogen fertilizer) may be plowed under in the spring and again in the fall. If a legume hay is used, no nitrogen fertilizer need be added as the legume hay contains enough nitrogen to decompose readily when it is incorporated in the soil. (b) To soil which is quite low in fertility, phosphorus and potash fertilizers, such as superphosphate 250–300 pounds per acre and muriate of potash 50–100 pounds per acre, often may be profitably applied; or a complete fertilizer may be used. Phosphorus and

* In some cases, as in the tests of L. P. Latimer in New Hampshire, Na cations stunt the plant through a reduced leaf area and a shortened petiole. This effect has been more marked with Na than with Ca or NH_4 cations when these were combined separately with NO_3, PO_4, and SO_4 anions.

potash do not leach as readily as nitrogen, and so some of the quantity of these elements applied to preceding crops may be available for the berries. (c) During the first year, nitrogen fertilizer sometimes is helpful on soils of low fertility, about a month after planting and again in mid-August or early September. (d) Occasionally, after winters of excessive snows or rains, the use of nitrogen may be advisable early in the spring of the fruiting year, though the extra moisture may offset the need for fertilizer unless the soil is markedly deficient in fertility. (e) When renewing the beds a complete fertilizer, high in nitrogen, should be applied. (f) The fertilizer program should take into account the growth status of the plants and factors such as prospective market prices.

Commercial fertilizer applied when fitting the soil for planting is usually drilled in. Care should be taken in applying nitrogen fertilizers to avoid damage by burning. Applying the material near the plants but not in direct contact with the foliage, crowns, or roots, either by hand or with a small drill, is safe procedure. Application of such fertilizer should be done when the foliage is dry. If a heavy rain immediately follows this application very little injury from burning will result. If a timely rain does not occur, it is wise to drag a broom or a burlap sack over the plants to brush off any fertilizer on them. Sometimes the fertilizer is applied on top of the mulch over the plants.

Southern Regions. Southern soils leach all winter and are, as a rule, low in organic matter. The growers need to use fertilizers liberally.

Some suggestions are:[252] Gulf Coast region, 1,000–1,500 pounds per acre of a 5-15-5 fertilizer, applied when the beds are being prepared. Some of this amount may be used later as a sidedressing. In this case the plant rows are barred-off shallow to prevent burning of the roots before covering. When placed in the row prior to planting, less fertilizer may be used than when broadcast. In southern and central Alabama, 500–600 pounds per acre of 8-6-8 fertilizer may be worked into the soil before the plants are set. Two sidedressings might well be used, one in August and another the last week of September to November 1, according to the soil fertility. A light application of 200–300 pounds sometimes is needed in February preceding harvest. However, usually 75–100 pounds per acre of a quickly available form of nitrogen is sufficient. In certain areas, 50–100 pounds of potash are applied as a topdressing in early spring.

In North Carolina,[180] the common practice is to use 1,000–1,500

pounds of "complete" fertilizer per acre, half in September or October and half in December, January, or February. A high percentage of nitrogen helps to give large yields of early berries.

In Arkansas,[135] there are two critical periods when fertilizer is the most valuable on bearing fields: after harvest to encourage the production of new plants and the initiation of fruit buds for the next crop, and in early February preceding the crop to encourage plant growth and full development of flowers and the setting and development of the berries. These two seasons are too widely separated for one application of nitrogen and potash to supply the needs of the plants during critical periods. The heavier the soil the more nearly a single application suffices. If only one application is made, February is the best time. In March applications the fertilizer moves downward so slowly in the soil that it does not reach the roots in time to be used to the fullest extent. A 1-3-1 ratio seems best for Newtonia soils, e.g., 500–600 pounds of 4-12-4, applied half in February and half in June.

On Ruston soils a 1-2-1 fertilizer ratio is desirable. Fertilizer needs can be supplied by using 600–750 pounds of 5-10-5 fertilizer, half in February and half in June or as soon thereafter as there is sufficient soil moisture to encourage growth. The amount of organic matter in the soil is also significant. Annual applications of manure to bearing fields on Newtonia soils do not pay because of the competition of weeds and grass from seed brought in with the manure. On Ruston fine sandy loam, annual applications of manure are profitable. The building up of soil by the use of manure and the turning under of the green crops before the plants are set greatly increases yield.

Effect of Fertilizer on Firmness and Flavor of Berries

Claims are frequently made that nitrogen fertilizer makes the fruit softer and of inferior handling quality. Such claims assume importance in cultural work and in marketing, particularly because increased yields are often possible from timely nitrogen fertilizer applications and because the fruit of the strawberry is, even normally, a highly perishable commodity.

For at least 25 years, bone meal was thought to be the only fertilizer that could be used to produce a firm berry. Bone meal is a good fertilizer for strawberries, though not necessarily the best or cheapest. The prefer-

ence for bone meal is probably largely associated with its phosphorus content. It is true strawberries are shipped from the South to distant markets and large quantities of phosphorus fertilizer are applied. This might seem to be circumstantial evidence that there is a correlation between the element phosphorus and the firmness of the resulting berries. This may be partly true. In Louisiana,[171] for example, phosphorus proved quite beneficial in increasing the size and firmness of berries and reducing the proportion of culls.

In a year that was excessively dry in Ohio:[124] (a) Slightly softer berries, in mechanical pressure tests, resulted from spring use of nitrogen. (b) Differences in moisture content were slight and not consistent between berries from fertilized and check plants. (c) The nitrogen content of the fruit was increased by fertilizing with nitrogen in early spring of the fruiting years. (d) The catalase activity of both fruit and foliage was increased by the nitrogen treatment. (e) A consistently lower percentage of reducing sugars, a lower percentage of total sugars in most cases, and fluctuating relative values for sucrose resulted from fertilizing with nitrogen. The percentages of reducing sugars, sucrose, and total sugars increased with successive pickings. (f) The pH of the juice of the berries from the check plots was lower than that from the nitrogen plots, i.e., less acid berries throughout the picking season occurred in the nitrogen plots. (g) The fruit was not so soft nor of such inferior handling quality as to preclude the spring use of nitrogen if such treatment would otherwise improve the crop.

In England,[285] the nitrogen content of the fruits decreased during the picking season and was highest in those fruits from plots which had received inorganic manures. There was a negative correlation between nitrogen content and acidity and also between nitrogen content and total sugars. Throughout the season the acid content of the fruits fluctuated unevenly, but tended to decrease slightly; the total sugars and sucrose showed a gradual increase, and the reducing sugars varied irregularly.

If an increased amount of nitrogen in the fruit results in greater respiration intensity, an application of phosphorus might lower the intensity by tending to lessen the nitrogen intake. In Washington,[343] the berries from the nitrogen plots tended to be softer and those from the extra nitrogen plots much softer than those from the checks. In Michigan,[305] fertilizer did not materially affect moisture content, texture, or quality of fruit.

In Alabama,[284] the weather, especially rainfall, affected the composition of berries more than did fertilizer. In general, the moisture and sugar contents of berries from watered plots were about constant during the season; whereas, the moisture content of berries from the checks decreased during the season, and the sugar content increased. The drier the soil became, the lower was the moisture content in the berries. Berries from checks were slightly firmer and smaller than those from watered plots. These differences were not exactly comparable to those between berries picked during rainy and dry periods, respectively, which reflect the influence of atmospheric humidity as well as soil moisture. Moderate use of

nitrate of soda under some conditions[257] had a slightly adverse effect on the berries. Between berries grown with and without irrigation, the differences in total sugars reached 3.32 per cent as compared with 0.72 per cent on check plots which had been receiving differential fertilizer treatments.

At Willard, N. C.,[164] Missionary berries from potash plots were sour and lacking in flavor. Those from the superphosphate plots were sweeter and better in flavor; those from the superphosphate plus nitrogen (tankage plus nitrate of soda) plots were much the sweetest. Berries from the control and from the nitrogen (tankage) plots were more sour than those from the superphosphate plots. With Blakemore, berries from the phosphorus and nitrogen plots were the best flavored and from the potash plots the poorest. Specialists in the National Preservers Association Research Laboratory in Washington, D. C., reported that preserves from the plots receiving nitrogen, nitrogen plus phosphorus, and phosphorus, were markedly superior to preserves made from berries from the potassium, and potassium plus nitrogen, plots.

The chemical composition of strawberry fruits is determined throughout the season by the absorption of water and the accumulation of sugar. These two processes are usually affected in their relative activity more by

Table 27

AVERAGE COMPOSITION OF 12 RIPE STRAWBERRY VARIETIES[145]

Variety	*Total Solids* (%)	*Soluble Solids* (%)	*Sugars* (%)	*Insoluble Solids* (%)	*Titratable Acidity* (%)	*Total Astringency* (%)	*Tannin* (%)	*Non-tannin* (%)
Aroma	9.77	6.48	4.63	3.29	0.593	0.365	0.217	0.148
Chesapeake	10.93	7.61	5.88	3.33	0.745	0.303	0.162	0.141
Dunlap	10.11	6.33	4.27	3.79	0.736	0.321	0.183	0.138
Gandy	11.97	8.35	6.34	3.62	0.972	0.384	0.210	0.174
Howard 17	9.95	6.96	5.04	3.00	0.780	0.289	0.177	0.112
Klondike	10.63	7.37	4.99	3.26	0.969	0.378	0.238	0.140
Missionary	10.89	7.33	5.26	3.56	0.772	0.389	0.217	0.172
New York	11.66	8.46	6.53	3.19	0.656	0.275	0.114	0.161
Parsons	9.29	6.16	4.49	3.13	0.699	0.354	0.203	0.151
Portia	9.08	5.96	4.35	3.12	0.586	0.280	0.138	0.142
Progressive	9.73	6.32	4.68	3.41	0.628	0.272	0.152	0.120
Sample	9.38	6.27	4.55	3.11	0.613	0.362	0.195	0.167
Average	10.16%	6.87%	5.00%	3.29%	0.705%	0.319%	0.178%	0.141%

weather conditions than by type and amount of fertilizers. Varieties may be arranged into at least four groups:[145] (a) low sugar, low acid, low

astringency, e.g., Portia and Progressive; (b) low sugar, low acid, high astringency, e.g., Aroma, Parsons, Sample; (c) medium sugar, high acid, medium astringency, e.g., Dunlap, Premier, Gandy, Klondike, Missionary; (d) high sugar, low acid, low astringency, e.g., Chesapeake and New York. None of the varieties is especially well adapted to preservers' use, primarily because the ratios of acidity and astringency to sugar content which are acceptable in a fresh fruit are too low to permit retention of balanced flavor and palatability when the fruit is preserved with sugar. Of the several groups, the medium-sugar, high-acid, medium-astringency group most nearly approaches the type of chemical composition desirable in a berry for preserving.

RENEWING STRAWBERRY PLANTINGS

Renewal should be done soon after harvest in order to provide a maximum time in which the young plants can form a good root system and crown. Reduction in the number of established plants reduces the demand for moisture and nutrients. With respect to the time of renewal; it should be borne in mind, as previously indicated, that the later the runner plants root the lower is their yield; also, that parent plants which have borne one crop are relatively high producers. Renewal is rarely practiced with plants in hills.

Removal of Mulch

Soon after harvest, the mulch between the rows, especially if heavy, should be gathered up and removed from the field, or be burned. No more should be left than can be readily incorporated in the soil, or will burn rapidly.

Mowing the Foliage

Frequently the tops of the plants are mowed soon after harvest, with the cutter bar of the mower carried high enough to avoid injury to the crowns. Mowing, provided the mowings are removed from the field, or burned, is a partial control for leaf-spot diseases. However, fungi live over winter on infected leaves, and if some of the diseased leaves are left behind, mowing will not be very effective in leaf-spot control.

Some claim that mowing is a sanitary process for the beds, that growth is stimulated, and that further renewal is facilitated. Others claim that

removal of healthy foliage is detrimental and stunts development of the plants. Information on the subject is as follows:[171] Within certain limits at least, the smaller the leaf area, the greater is the transpiration per unit of leaf area. If a part of the leaf area is removed, the remaining leaves transpire more water than they otherwise would do. Presumably, also, stomata of the leaves on plants where the leaf area has been reduced are open more of the time and function more effectively in photosynthesis than do stomata on many-leaved plants. This response of leaves may have a bearing on the practice of topping the plants after the harvest season, for a relatively small amount of new foliage may be as efficient as a much larger amount of old foliage.

The cutting off of the leaves or topping of strawberry plants, following harvest, is rather common practice in the Pacific Northwest, for reasons such as control of leaf spot, cutting down leaf surface to lessen the loss of water during the dry summers, and control of the crown borer or moth. Topping, when practiced, should follow immediately after harvest. Delaying the topping after harvest has decreased the yield the next year in Oregon. The tops may be cut off with hand scythes, knives, sickles, or a mowing machine. Careless handling of the mowing machine may result in damage to the crowns; then, too, it does not cut off all the tops.

In Oregon,[489] covering plants 2–3 inches deep with soil did not impair yields under ample moisture conditions, but under summer drought conditions did affect yields unfavorably. Topping plus covering did not impair yields under ample moisture conditions and resulted in slightly increased yields. However, under drought conditions much lower yields resulted than from the checks. Topping alone resulted in increased yields under ample moisture and had no adverse effect under drought conditions. Topped plants produced far less runners than did both the covered non-topped and those in the checks under conditions of ample moisture. The very large plants produced in the year following a summer drought by plants previously covered, indicated that covered plants which survived the drought and which bore less fruit were more vigorous after the harvest than the checks. Such covered plants producing the most runners were not quite so large as the checks by October. Topping after the first crop was beneficial even apart from its use to control the crown moth. Covering or topping-plus-covering is helpful provided the soil moisture is ample. The root systems should not be disturbed in procuring soil for covering. Covering with soil changed the normal structure of the plant. Covered crowns were elongated, sometimes to three or four inches. When the main crown or crowns died, new ones developed from lower down. Plants covered with soil resembled the structure of the native wild strawberry *Fragaria chilensis* as it grows on shifting sandy beaches.

Burning Over the Beds

When practiced after harvest this is done to destroy old foliage and to reduce weeds, leaf-spot diseases, and other troubles. Though burning may be helpful, where the field is too weedy, diseased, or infested with insects it may be unwise to attempt renewal. Burning should not be done until the mowed foliage and mulch are relatively dry, but the soil moist, and until there is sufficient breeze to sweep the blaze quickly across the field. Should the burning be done during a prolonged drought period, the plants may be damaged. Damp foliage or mulch may result in slow passage of the fire and injury to the plants. To overcome this difficulty, shake and loosely scatter some of the driest of the mulch over the planting. The process is helped by placing burning material, with a fork, at advantageous positions throughout the field. Inexperienced growers often are unduly alarmed by the appearance of the field, but seldom is the damage serious if a rain follows soon after burning. Some mulching materials are difficult to burn properly and some varieties are more sensitive to heat than others. Burning destroys unrooted runners, particularly the early-formed ones, which otherwise might develop into fruitful plants after cultivation of the soil.

In the Masstown-Debert area in Nova Scotia the practice has gradually evolved of burning the mulch off the field in the spring prior to the first crop. The reasons are these: (a) It seems to give a fairly good measure of control for the strawberry weevil, as weevil populations under this treatment rarely build up to the point where they cause much damage. (b) It seems to help materially in the control of mildew and leaf scorch. The success of the method in Nova Scotia may also be partially due to the fact that in general a fairly wide matted row is used with a relatively narrow walk between the rows and soils are mostly medium deep sandy loams, and so there is little difficulty with sand or soil getting on the berries and also considerable quantities of manure are available for use in the fields prior to planting and for the crop itself. This burning is usually done quite early, usually near the end of April, when the mulch is dry but when the ground under the mulch is wet. A good brisk wind is wanted so the area will burn over rapidly. Under these conditions the foliage is burned from the plants but there rarely seems to be any damage done to the crowns.

Narrowing the Rows

Four systems of renewing beds are: (a) systematically turning under one side, so as to narrow the row and leave the newer plants on the outer edge of the remaining strip; (b) narrowing the row from both sides; (c)

working out the center of the row and leaving strips on both sides; and (d) rows not narrowed.

A plow may be used in the first method; a harrow or cultivator then levels the soil and tears out the plants that were turned under. Many growers claim that the results are not commensurate with the cost. The plants that were turned under are sometimes hoed out, but hoeing is laborious. Yet to leave these plants is not conducive to best success. It is not easy to tear out the plants and work the soil between the rows into good condition soon after plowing. When the rows are not more than 3–3½ feet apart and an ordinary farm plow is used, the adjoining rows sometimes become covered with soil; a light covering of soil thrown up to plants of varieties with relatively high crowns, such as Premier, may be of some benefit but too much covering damages the plants. As a time saver, a small two-way plow is preferable to an ordinary plow.

An elevator type of potato digger may be used as it possesses some advantages over the plow for narrowing the rows, but it is not very satisfactory. The rotary hoe, with long sharp prongs, may prove useful where the ground is free from stones.

A grape hoe may be used for narrowing the rows. Before using it, the mulch is raked and removed from the planting, or is burned. The hoe should be sharp so that it penetrates about 1½ inches deep. It may sometimes be necessary to tie a weight, such as a heavy stone, on it. About half of each row, always the same side of the row, is sliced off and the plants between the rows are laid up so that they may be gathered much more readily than when a plow is used to narrow the rows. Later, by running a cultivator between the rows the soil can be put into excellent condition.

A system often followed is to narrow the rows slightly from both sides and leave the plants in the middle. Sometimes a small plow is used to turn a furrow from each side into the space between the rows. More frequently a cultivator with strong teeth is used on soil that is relatively light and not too dry.

Another system is to work through the middle of the row and leave a narrow strip along each side, usually by means of a type of plow especially adapted for this purpose.

Systems that do not narrow the rows depend primarily on thinning the plants in the row. In some cases the work cannot be undertaken until it is too late to do more than make a narrow pathway between the rows.

leaving nearly all the plants untouched. This plan is none too satisfactory, but in a dry season there may be no better way. Sometimes when the plants take longer than usual to develop green foliage after a burning, it may be unnecessary to narrow the rows any more than is done in the subsequent cultivations.

Thinning the Plants in the Row

Some purposes of thinning are to avoid too crowded conditions in the row, to remove old plants, and to afford opportunity for plants that are to fruit the next year to grow as large, vigorous and thrifty as possible. Some thinning of plants in a narrowed row is usually desirable but the necessity, time, system, and response depend to a certain extent on circumstances.

Weather conditions of late summer and fall, type and condition of soil, prevalence of weeds, age of planting, variety, and other factors affect the manner and degree of thinning. Thinning after renewal is a somewhat different proposition than during the year the plants are set, because in the second year, renewal follows fruiting. When the plants are crowded, with favorable conditions, early-thinned rows may show advantages over unthinned rows or those in which thinning was delayed after renewal, provided the most productive type of plants was left and inferior ones removed. But, when conditions are unfavorable, better results may be obtained by leaving the narrowed rows with a later or reduced amount of thinning, or even without thinning. As a rule, when the work is done soon after harvest, adequate time is afforded for well spaced, strong, healthy plants to make good crown growth. It should be borne in mind that early-rooted plants are more productive than those rooted late.

With Blakemore grown under a thinned-row system, greater yields are obtained from the renewal system by which all runners are removed and the original plants fruited the second year than from either the conventional renewal system or reversion to the matted row.[139] When thinned rows are allowed to revert to the matted row for a second crop, yields equal to a conventional "barring off" may be obtained. Compared with first-year yields, fruiting the original plants the second year results in a reduction in yield of only 10 per cent, whereas with the two other renewal systems decreases of 40 per cent may occur. This is because plants under the two-year plant renewal system are able to accumulate larger leaf areas,

root systems, and food reserves. Greater yields are obtained from 10-inch-wide rows with progressively lower yields from the 20-, 30-, and 40-inch-wide rows, regardless of the renewal system used.

In another experiment with Blakemore,[336] these renovation practices were compared: (a) In the renewal of the triple row bed both side rows were plowed up: (b) in the matted row, a portion of the bed was plowed up on each side, leaving a strip 6–8 inches wide; (c) the double row was renewed by taking out two of every three plants in each of the rows making up the double-row bed. In each case, about two thirds of the old plants were destroyed. New runners were then allowed to reform the beds as before, but full stands were not obtained under any of the treatments. In the old beds of each type, all the plants were left to fruit for a second year. The two-year beds produced greater yields than did renovated beds in both years. The berries were larger on the one-year plants, but the differences in size and grade were not enough to make up for the much lower yields in comparison with the old beds. Yield was greater by 61 per cent on the old double row, 22 per cent on the old triple row, and 57 per cent on the old matted row than on the corresponding renovated beds, which produced respectively about 2,300, 4,000, and 3,100 quarts per acre.

Fertilizing and Cultivating When Renewing Rows

The kind and amount of fertilizer to apply when renewing plantings depends on the age, vigor, and stand of plants, the plant-forming habit of the variety, and on other factors. Use of 250 pounds of a nitrogen fertilizer, such as sulfate of ammonia, has given good results in many cases. Superphosphate, 250–300 pounds per acre, has been beneficial but less so than the nitrogen fertilizer; likewise, potassium fertilizer, such as muriate of potash, 50–100 pounds per acre, is beneficial. A high-grade complete fertilizer is suitable at this time.

The following deductions in regard to a second crop were made at Ottawa, Canada:[318] (a) Even on soils that seem in good tilth nitrogen fertilizer has a distinct value and may increase yield. The need for this extra nitrogen may not be detectable by observation of the plants. (b) Use of nitrogen fertilizer during the first fruiting year materially affects the yield the second year. (c) August 15 (of the first fruiting year) is as late a date as advisable to apply nitrogen fertilizer for best results. (d) Though spring applications may increase the size of fruit, they are of doubtful value for the second crop, but apparently quite safe for the first.

The soil between the rows should be cultivated thoroughly soon after renewal.

HARVESTING AND MARKETING STRAWBERRIES

Containers

Six types of berry boxes are in use—The American, Hallock, Leslie, stitched tray, metal rim, and paper, and there are crates for each of these types. The American quart box is used almost exclusively as the quart container in northern regions. It provides openings for ventilation at the corners and at the center of the sides near the top. The Hallock box is square, with solid sides and bottom, and the bottom is raised to prevent bruising of the berries in a lower tier. The Leslie box is octagonal. As with the Hallock, the bottom is raised, no dividers are used, and it is shipped in the flat. The Leslie box has been used mostly in the Mississippi Valley. Pint boxes of various types are used in the earliest shipping regions and sometimes for the everbearing crop. Crates holding 16, 24, or 32 quarts or pints or other amounts are used; the 24-quart crate is the most popular. In Ontario, the 27-quart crate (three layers of nine boxes each is commonly used). The crates and boxes should be neat, clean, and undamaged. Cardboard crates are attractive and can be printed in color. Demand and price for berries are adversely affected when offered for sale in damaged or unattractive packages.

Stage of Ripeness

The proper stage of ripeness as determined by color depends on such factors as variety and distance to market. For long shipments the berries are often picked while showing some green or white color and while still hard. However, picking berries which are not sufficiently colored is not conducive to the making of a good reputation for the crop of that particular area. Kentucky is known favorably for the splendid grade of strawberries which it markets. Here close supervision of the pickers is practiced, the plantings are picked over every other day, and berries with green tips are rated as "culls" even for distant markets. Thus, it appears that berries picked immediately after reaching full color stand shipment for reasonably long journeys. Berries that have stood in the field 24 hours or more after reaching good color are unsatisfactory for shipment.

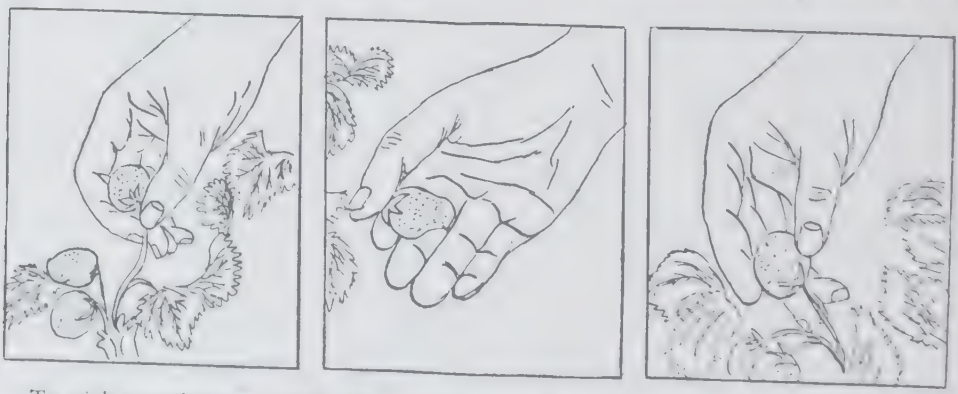
Usually, the berries should be picked every other day. Certain varieties may be left three days between pickings, whereas others should be picked daily.

Pickers and Picking

The number of pickers needed varies with their efficiency and the crop. Though many of the pickers may be needed for only a relatively short time, growers often need extra help from early spring to late fall for such work as setting plants, transplanting vegetables, weeding, thinning fruit, renewing beds, spraying and picking tree fruits, and for other operations. With a yield of 3,200 quarts per acre, five or six pickers working every day should take care of an acre. Many growers like to have enough pickers to complete picking before noon to avoid the heating of berries in full sunlight of midday.

Good supervision of the pickers is important. They should be instructed at the start regarding the stage of ripeness or color, clean picking, picking by the stem instead of by grasping the berry, sorting while picking, filling the boxes, care in handling, avoidance of kneeling on the plants, disposition of the boxes, and other details. Stems should be left ¼–½ inch long on the berries. Carriers or trays, with handles, that hold four, six, or eight boxes should be provided for the pickers in commercial fields.

Careful handling is necessary. Berries crush easily and then are not attractive as market fruit. Overripe and unsound berries should be picked from the plants, even though worthless, to avoid having some of them get into later pickings. Only a few berries should be held in the hand at a time. Fruit that is overripe, that is picked when wet, or that has become soft or bruised in picking or handling is soon attacked by molds and



To pick strawberries, pinch off stem between thumb and forefinger, leaving part of stem attached to berry. Bruising will result if berry is pulled or grasped as shown in the illustration of incorrect methods. (Courtesy, J. D. Winter, University of Minnesota.)

A cheaply constructed shelter shed serves a number of useful purposes in the strawberry planting.

decays quickly. Berries not marketed directly from the field should be placed at once in cold storage, a cool cellar, or other suitable place in order to delay deterioration.

Berries for processing may be capped by the pickers. The fruit is removed leaving the calyx (cap) on the plant. To do this, the picker uses both hands. This plan is usually more economical than picking and capping in separate operations. A capper* is quite efficient on firm varieties with necked fruits in which the calyx stands out from the berry. Varieties which have a tight calyx and slightly sunken calyx attachments are more difficult to cap. This mechanical capper does not seem well adapted to comparatively soft berries.

Most pickers are paid by piece work, though many are paid by the hour or day. Often the pickers take the carriers or trays to the shelter shed where they receive credit for the quantity picked. In large fields it is usually necessary to use some systematic method of keeping a record of the work done by the pickers. The punch card system is probably the most commonly used but like the other systems such as the book, check, or cash, has drawbacks as well as advantages. When pickers work by piece work, they are wont to pick where the berries are thickest, to leave the scattered

* The Tennessee strawberry capper was invented by A. H. Morgan. The patents are managed by the University of Tennessee Research Corporation. The model is barrel shaped and has many small spindles that remove the strawberry calyx or cap.

fruit, and to fill the boxes as fast as they can, sometimes without due regard to careful handling or sorting. When pickers are paid by the hour, they may not work as fast as they should. A common rate in paying is one fifth what the grower receives for the berries.

The berries should not be allowed to remain exposed to sun, wind, or dust. A shelter shed can often be used to advantage; it need not be an elaborate structure but should be so located that the pickers have a minimum walk when bringing in the fruit and that it can be reached conveniently by truck or horse-drawn vehicle. Many growers use a structure with simply a roof and a wall on the side of the prevailing wind. Careful supervision at the shelter shed is important.

The length of time that the fruit will keep after picking depends upon the variety, the degree of ripeness, the care with which it is handled, and the temperature of the berries at the time they are picked or at which they are held after picking. For each rise of about 15° F., the life of the berry, other things being equal, is decreased one half; that is, if the strawberry will keep for eight days in good condition at 40°, it will keep for only one day at 85°.[149] If the berries are picked in early morning when they are relatively cool and put at once in the shade, they will keep longer and have a much better appearance on the market than if picked at midday when they are warmer or if left in the sun after picking.

Table 28

TEMPERATURE OF STRAWBERRIES WHEN PICKED IN MISSOURI[150]

Time	*6.00*	*7.00*	*8.00*	*9.00*	*10.00*	*11.00*	*12.00*	*1.00*	*2.00*	*3.00*	*4.00*	*5.00*	*6.00*
Berries	45	46	53	63	68	74	77	77	79	82	79	72	63
Air	45	45	50	51	54	63	60	63	63	66	64	62	61
Difference	0	1	3	12	14	11	17	14	16	16	15	10	2

At Monett, Mo.,[151] the temperature of the berries was much higher than that of the surrounding air, Table 28. At 6 a.m. the temperature of the air and berries was the same. By 9 a.m. there was a decided difference. The difference was greatest at noon, though nearly as great from 12 to 4 p.m. Cooling the berries in the shade reduces the temperature greatly, making them keep longer. Dew on the berries, in most cases, does not injure their keeping quality.

The respiratory intensity of fruit is significant from the standpoint of storage and handling.[236] It is a measure of the rate at which metabolism is proceeding, and as such is often considered an indication of the potential storage life of the fruit, a high respiratory intensity being associated with a short storage life. As a measure of metabolism, respiratory intensity may also indicate the rate at which the fruit is deteriorating in dessert quality and food value. From the respiratory rate it is also possible to estimate the heat of respiration, which under some conditions is an important factor in the refrigeration of a product. The life of strawberries after harvest is short compared with apples, pears, and citrus fruits. Associated with this short life is a relatively high rate of respiration. Among strawberry varieties, however, a high rate of respiration on a fresh-weight basis is associated with firm berries of relatively good shipping quality, e.g., Blakemore, Aroma, Klondike. The firm varieties are high in percentage of total solids, and their high respiratory activity is presumably due very largely to the greater amount of respirable material per unit of fresh weight. The respiratory rate of strawberries increases about 50 per cent from the immature to the mature stage. There is also an increase in respiratory activity of ripe berries picked later in the season. The respiratory rate increases greatly with a rise in temperature and is 13 times as great at 80° F. as at 32° F.

Grading and Packing Strawberries

Fruits of different grades can be put in different boxes in the carriers or trays. Grading in the field tends toward a minimum of handling but requires close field supervision, and a crop of good quality which is in good condition. Grading at the packing shed frequently consists in pouring the berries from one box or cup to another and removing the culls. It may be essential, especially in shipping areas, if a large percentage of the crop is below U.S. No. 1, or if careful pickers cannot be secured. The pan method is usually more satisfactory and consists of emptying each box into a tin grading pan and removing the defective berries as the fruit is poured back into a box. Southern berries are usually picked firmer than northern ones. Local trade berries are seldom graded, other than some sorting while picking.

Packing, when practiced, usually means arranging the top layer of berries so that no stems show and a neat appearance is obtained. When the crop is especially good or the market is not too critical, it may not

The pan method of sorting and inspecting berries of firm varieties. The strawberries are emptied from a box into a tin grading pan, and the defective berries are removed as the fruit is gently poured back into the box. (Courtesy, E. J. Hoddy, Louisville & Nashville Railroad Co.)

pay to do more than remove the culls. For critical markets, it is often advisable to select according to definite grades.

Strawberry Auctions

The Strawberry Yard, or Sales by Individual Growers. The grower brings his fruit to the strawberry "yard," "platform," or "shed" where it is inspected and bid by shippers consisting of local men, fruit brokers or representatives of northern commission houses. The highest bidder pays the grower for the fruit as soon as it is delivered to the proper car or platform for shipment. The charge to growers for selling through the auction is low because the overhead expense is small, and the operating expense is usually limited to the pay of an auctioneer and clerk, possibly some help in opening packages for inspection and in handling them, and in some instances demurrage on cars. In a few instances the auction company makes a charge to buyers as well as sellers.

Advantages cited for this method of selling are:[330] (a) The product sells on its merit in competition with that of other growers and a premium in price is paid for good quality and pack; thus, good production methods and proper grading and packing are encouraged. (b) The grower receives payment promptly and does not have any trouble with adjustments. (c)

The publicity enables the buyers to operate intelligently and establish a more stable market. (d) The concentration of supply and buying power establishes confidence among buyers and growers. (e) Buyers are better able to select the grades needed by their trade. Objections on the shipping-point auctions selling growers' loads are: (a) The possibility of control of prices by the buyers through collusion, though this is not common. (b) At times there may not be enough buyers to insure satisfactory prices. (c) There may not always be sufficient volume of products to attract adequate buying power. One requisite of a successful auction is that the supply be regular and large enough through the shipping season so that buyers will find it worthwhile to patronize the auction.

The auctions in which sales are mostly in wagonloads or truckloads by growers are located chiefly along the Eastern Shore from Maryland to North Carolina, and south to Florida. Reports from the Eastern Shore of Maryland indicate that the auction method has been used since about 1912 and on the Eastern Shore of Virginia since about 1917. In New Jersey, this method of selling came into some use in 1928.

THE "SET-OFF." The grower does not take his fruit to the "yard" to have it bid upon but sets it off at the platform of some shipper to whom he may be financially obligated or with whom he desires to deal. He is not paid for the fruit until the next day, when he may be given the average "yard" price, or slightly higher, for his fruit.

SALES IN CARLOADS BY GROWERS' ASSOCIATIONS. Much of the crop in the early-producing states is sold in carloads at auction to the highest bidders. This method came into use shortly before World War I. Growers' associations take care of loading the cars. In the evening the loaded cars are auctioned off. The price paid the grower is the price bid on the car in which he loaded his fruit less charges for loading and selling.

Carlot auctions are located at Hammond, La. The auction method places the small buyers on an equal basis with the large buyers or speculators who at times practically controlled the situation before the method was used. The auctions are incorporated and deal with associations of growers and not with individual growers direct. The auctions have cooperative features and may at times make rebates to the associations which ship through them, on a package basis or according to stock owned. The local associations of growers furnish packages and load the cars. The carlot shipments, all of which are in refrigerated express cars, are inspected under the Federal-State service. Cars loaded during a day are sold the same night. During the season sales are held every day, including Sunday. The sale starts from 7.30 to 9.30 p.m. and may last till midnight. Usually many buyers are present.

consisting of brokers or representatives of city dealers. Before the sale each buyer is furnished a catalog which gives car numbers and initials, loading points, brands, and other pertinent information concerning the cars which are "rolled" each night toward Mattoon, Ill., a division point. The cars start rolling before the auction begins and may be several hundred miles away when the buyers are bidding. The auction company can withdraw a car at any time during the sale if a satisfactory bid is not obtained. At times the auction company may have cars bid in when the price offered is considered too low. This practice has been criticized by the buyers, who claim that an artificial price situation may result and that goods belonging to the seller may enter into competition with the buyers' goods on the markets. This practice has been defended, however, on the ground that it is necessary for the protection of the growers.[350]

Shipping Strawberries in the Pony Refrigerator

Prior to 1929 most of the Florida strawberry crop was shipped in heavy double-walled wooden cases known as pony refrigerators. The case, made of cypress, usually holds 80 quart boxes, though some hold 64 or 32 quarts. Metal trays in the center and top of the case hold a supply of ice. Drainage of melted ice is effected through a hole from the top pan into the center ice pan and thence through a drain to the outside. These pony refrigerators are returned to the shipper when emptied and are used several times each season. If properly stored when not in use they last for several years. They are well adapted to long-distance express shipment, especially where it is impossible to load full cars and when prices are high. Sometimes the ice pans sweat and allow water to drop on the berries. In 1929 new tariffs established by the transportation companies made it possible to ship strawberries out of Florida more economically in crates in carload lots.

Shipping Strawberries by Refrigerated Car and Express

The refrigerator car was evolved by Parker Earle, Cobden, Ill. By 1866, he had become a leading strawberry grower at that place. Having had difficulty in shipping the berries to Chicago he devised and built 12 refrigerator chests, much similar to the pony refrigerator. These held 200 quarts of berries and 100 pounds of ice. Shipments were made to Chicago, Pittsburgh, Memphis, and New Orleans with success, but the high rates and the difficulty of re-icing stopped the venture. Mr. Earle then arranged for the shipment of a car of berries from Cobden to Chicago in a refrigerator car which had been patented by J. B. Sutherland, of Detroit. The car was cooled by ice and salt placed in tanks which were refilled from the roof. Owing to poorly distributed refrigeration the shipment was a failure.

He then built a precooling plant at Anna, Ill., which was the first one ever built. Fruit held in this for 24 hours arrived in good condition. For a three-day trip, an ice capacity of five tons proved necessary. He finally persuaded the car manufacturers to build such a car. This contribution added millions to the wealth of growers all over the country.

The acreage near the shipping point should be sufficient to load at least one car daily. This requires[474] 75–100 acres located within a radius of not more than 3–4 miles from the shipping point. Most commercial districts in Missouri, for example, load 420 24-quart crates into a standard refrigerator car. These are usually placed in the car four crates high, seven crates wide, and 15 crates long, and properly braced.

The fast refrigerated express service offered by railroads in some districts in 1930 was a marked improvement in transportation facilities.

Trucking Strawberries

Strawberries, though a highly perishable commodity, are well adapted to truck transportation on smooth roads over a reasonable mileage. Successful trucking has led to a decline in production near large cities and an increase in more remote areas where land and labor are cheaper. Truck delivery of berries should be expeditious and made in the cool of the night as much as possible.

Though trucking offers many advantages it also has some drawbacks. Sometimes it causes violent fluctuations in prices and supplies. Advance reports on truck loads are made with more difficulty than are those for rail shipments. Also, instances have occurred where berries in southern regions, too soft, because of rain, for rail shipment, have been trucked to markets and have glutted and demoralized them. In such cases, the truck shipment, at best, provides a partial income instead of a complete loss through non-shipment. Such shipments, in competing areas, ruin the market for some time.

FROZEN-PACK PRESERVATION OF BERRIES

For best results, berries must be frozen quickly. The temperature of the berries should be reduced so fast that deteriorative changes are quickly retarded. Slow freezing of fruits disrupts their cell structure, causing a loss in flavor and firmness. Once they have been quick-frozen at a low tempera-

ture (e.g., −10° to −20° F.) the berries are kept steadily at 0° F. or lower.

Freezing berries does not sterilize them. It merely slows down the action of most types of enzymes and stops bacteria, molds, and yeasts. When the berries are allowed to thaw, such organisms proceed to grow. For this reason all frozen products should be used soon after being removed from the freezer.

Fruit preserved by the frozen-pack method is used: by pie bakeries, hotels, and restaurants; in the commercial manufacture of preserves, jams, and jellies; in the preparation of crushed fruit and fruit syrup for soda fountain use; for fruit extracts and flavors; in small packages for the direct consumer trade; in larger packages for hotels and restaurants; and in the preparation of ice cream. Frozen fruits, preferably in just the condition they come from the field, provide excellent specimens for discussion of varieties and other purposes in the classroom.

There are now at least three distinct aspects to the frozen-pack preservation of berries, viz., the commercial pack, frozen-food lockers, and home-freezer cabinets.

Commercial Pack

The commercial frozen-pack industry with berries began at Salem, Ore., about 1910. In the East, leading early centers arose at Norfolk and Baltimore. Today, berries of various kinds are packed commercially in nearly all areas where small fruits are important crops.

If berries are rapidly prepared and quickly frozen, decay is stopped and other changes retarded. After freezing, they are kept in cold storage until used; the period may range from the time of harvest in one year until fresh berries become plentiful the next year.

Handling. The hulls of strawberries are removed before the berries are graded and processed, either in the field or at the packing house before the final inspection. Preferably, the fruit should be picked in the cooler part of the day and be delivered the same day it is picked. In the Northwest, the berries are brought from the field in crates holding 12–15 pounds; in the East, the 24- or 32-quart crates are used for all berries, except red raspberries for which the pint container finds favor. The fruit is washed, preferably with a spray washer. As little water as possible should be carried into the package, since added water is an adulterant according to the Food and Drug Law.

GRADING. Though the grading methods employed in the Northwest are numerous, sizing is usually done[314] on either a screen- or a rod-type shaker grader which sifts out fruit according to the perforation of the screen or the spacing between the rods. The graded fruits fall from the grader upon the conveyor belts which travel at a speed of 30–40 feet per minute. Sorting out imperfect fruits is done by workers located at one or both sides of a well-lighted belt. As the belts move from the grader they carry the fruit either to barrels, cans, or cartons for freezing. Filling arrangements at the end of the belt are designed to cut to a minimum the number of workers necessary to handle the daily tonnage.

SUGAR. Strawberries are usually packed in sliced form with cane sugar; 3–6 parts by weight of berries to one part of sugar. Sugar is sometimes used with red raspberries, though the tendency is to omit it (straight pack). With tall containers, layers of sugar and berries are alternated, but with shallow ones all the sugar is placed on top. Black raspberries and blackberries are frozen with or without the addition of sugar, and, in the East, frequently in the boxes or crates. Sugar tends to draw the juice out of berries by osmotic action through the higher concentration of the solution around them.

The sugar used is usually a fine granulated manufacturers' grade, which is slightly coarser than the regular table grade. Too coarse a sugar dissolves slowly and detracts from the appearance of the product.

Syrup densities should be:[314] Strawberries, 60°–70° Balling; red raspberries, 60°; loganberries, 60°–70°; blackberries, 50°–60°. Usually, the higher density syrups detract from the flavor by overemphasizing the sweetness of the berries. Adding cold syrup (10° F.) speeds up freezing, retards mold growth, and adds to the quality of the fruit, especially when it is precooled by washing with cold water and passing the filled cans through a box or chamber kept at a low temperature.

FREEZING. Berries in cans or barrels are usually frozen at −10° to −20° F. Freezing-room methods at −10° to 10° F. are satisfactory when brine at 0° F. is used and circulated around the cans. The larger the package, the longer it should be held in sharp freeze before being placed in the holding rooms. To freeze a barrel to the center ordinarily requires five days; smaller containers require 24–30 hours; and berries in cartons require but a few hours. After the berries are properly frozen, they must be kept frozen, and no greater variance than 5° F. should be allowed.

Frozen-food Lockers

A sharp-freeze room or cabinet, which often contains air blast and metal freezing plates, is provided in modern freezer-locker plants for freezing the products before they are placed in the lockers. Not only can products be frozen more quickly, but the heat and moisture from the warm food is kept out of the locker, thus avoiding temperature fluctuations detrimental to the products already stored in the locker and in neighboring lockers.

Theoretically, the lower the storage temperature the better the product. For practical and economic reasons the industry has standardized on zero storage, considering zero to be the highest temperature at which frozen foods should be held. In locker rooms held at zero, with temperature fluctuations limited to 5° F., all fruit products, if properly prepared and packaged, should remain in good condition for a year or more. It is not expected that products will be held beyond the next production season, nor is it desirable or economical that locker space be so used.

Containers. The containers and wrapping materials used in freezer-lockers should be not only airtight and waterproof, but moisture-vapor proof. The zero air in the locker room is much drier than the outside air or even the air in a mechanical refrigerator. This dry air will draw out moisture from the frozen product through treated papers and other wrapping materials that under ordinary conditions would be considered airtight.

If there is a coating of frost on the inside of the locker, it is likely that some of the food is badly protected by non-moistureproof containers or wrappings. The presence of frost crystals inside the loose protective wrappings indicates that moisture has been drawn out of the food, and with the moisture has gone some of the fine flavor. This is especially noticeable if the storage room temperature has been allowed to fluctuate. Each time the temperature rises, moisture is drawn out of the food and is not reabsorbed when the temperature is lowered but remains in the form of ice crystals. Therefore, care should be taken to pack and wrap closely so as to exclude the air as much as possible.

In buying containers, it is wise to select the size or sizes which will best meet the family's requirements for serving or cooking at one time, and thus avoid partly used packages which deteriorate and spoil rapidly if allowed to thaw. Since the more quickly the food freezes the better the

quality, small containers which permit quick freezing to the center of the package are preferable. Fruits for making into preserves, or for other purposes where larger quantities are required, may be packed in larger containers.

Glass fruit jars, tin cans, heavily waxed paper cups, and miscellaneous containers that happen to be available, are also used in locker storage. Properly sealed, the glass and tin are moisture-vaporproof, but the glass is likely to break. Waxed-paper cups, such as are available for ice cream; cottage cheese, and similar products, usually give inadequate protection unless lined with a moisture-vaporproof material. Containers should be straight-sided to permit easy removal of the frozen contents. Rectangular containers permit the storage of at least one third more food in a locker or home storage unit than do round containers.

With liquid packs, a 10 per cent space must be allowed for expansion when freezing, otherwise the container will be broken by the expansion and leakage will result.

Dry Pack. The dry pack (without sugar) is used for fruits to be made into pies or for later processing into preserves, jelly, or juice. The fruit should be carefully sorted and, usually, washed. It should be well drained to remove excess water and to prevent freezing into a solid mass. Red raspberries and other delicate fruits may be packed without washing if they are carefully harvested, sorted, and cleaned to avoid dirty berries, insects, and other foreign matter.

Sugar Pack. The fruit may be packed whole or crushed. One pound of sugar to 3–6 pounds of fruit should be used, according to taste and the acidity of the fruit. The sugar and fruit should be well mixed, so that the fruit is thoroughly coated by the dissolved sugar and juice when placed in the freezer. All the sugar should be dissolved before freezing starts. The sugar pack or sugar-syrup pack is usually preferred to the dry pack when the fruit is intended for dessert purposes. The sugar penetrates the fruit more evenly and the flavor is better than if the sugar is added when the frozen fruit is served. Strawberries are packed whole for preserves; whole, sliced, or pureed for ice cream; and, sliced for home consumption.

Sugar-syrup Pack. The syrup helps to prevent dehydration and oxidation if the containers used are not strictly moisture-vaporproof, and protects the product to some extent from fluctuating temperatures in the locker room and during transportation to the home. It is not as

desirable as the dry and sugar packs for pies, preserves, and jellies, because of the additional water that must be cooked out, but is satisfactory for many dessert purposes. The fruit may be packed whole, sliced, chopped, or crushed, and then covered with 40 to 50 per cent syrup (2/3 to one cup sugar to one cup water). The sugar may be dissolved in hot water, but the syrup must be cold when added to the fruit.

Home Freezer Cabinets

These require separate freezing compartments for the same reason given for the sharp-freeze room. When ice cream and similar storage cabinets are used, small amounts only should be frozen at one time and preferably in an otherwise empty compartment to prevent temperature fluctuations in the stored food and overloading the freezing equipment.

Home Storage Units. These are intended by their manufacturers to be used for the storage of foods frozen by commercial companies specializing in frosted foods, or food processed at home and frozen in a locker plant. Since the "freezing capacity" of such units need not be high, the cabinets are not excessively expensive to buy or to operate.

Home Freezer Units. There are one or more compartments for storage of food at zero, and also a quick-freeze space capable of freezing a limited amount of food at home.

Dual Temperature Units. These provide one or more compartments for storage of frozen food at zero or below and the rest of the space is held at a temperature above freezing generally recommended for perishable foods such as milk, cream, butter, and fresh vegetables. They are useful for freezing and storage of a limited quantity of food. A larger unit is known as the "walk in" cooler.

CONTROLLING STRAWBERRY INSECTS AND DISEASES

Key to the More Important Strawberry Insects*

1. Injury to blossom buds
   (a) Small reddish brown or blackish snout beetles about 1/10 inch long cut blossom stems causing the buds to wilt, drop off, or hang by a thread..... Strawberry weevil

* As set forth later, nematodes are associated with certain diseases.

2. Injury to leaves
   (a) Small beetles eat holes in leaves giving the foliage a "shot-hole" appearance ..... Strawberry leaf beetle
   (b) Greenish or brownish caterpillars fold the leaves over, often across the midrib, and feed within the weblike shelters thus formed ..... Strawberry leaf roller
   (c) Foliage chewed during night by smooth, stout caterpillars which hide in the soil by day ..... Cutworms
   (d) Tiny red mites feed on the under surface of the leaves causing curl, and a necrotic discoloration ..... Red spider-mite
   (e) Larvae feed on the leaves and stems by inserting their mouthparts into the tissue, causing the leaves to become distorted. As development of the larvae occurs the spittle-like, slow-drying, frothy mass enlarges ..... Spittlebugs
3. Injury to roots
   (a) Large whitish grubs, with six distinct legs, eat off the roots and kill the plants..... White grubs
   (b) Small whitish grubs, with no distinct legs, feed on roots and weaken or kill the plants. Important in Pacific Coast areas.. Strawberry root weevils
4. Injury to crown
   (a) The larvae mine in the crown of the plant after completely destroying and reducing it to a mass of brownish frass. Pupal cases can often be found extended from the crown of the plant during the time the moths are in evidence. Serious in Pacific Northwest and South ..... Strawberry crown moth
   (b) Mites, which are white to light brown and hardly visible to the unaided eye, feed on young unfolded leaves in the crown, thus causing a stunting and dwarfing of the

leaves. Leaf stems short; leaves distorted. The chlorotic condition developing varies from a darker green in the young leaves to a yellowing in the advanced stage. . . . Strawberry crown mite (cyclamen mite)

5. Injury to collar
   (a) Plants cut off near ground level by smooth, stout caterpillars which hide in the soil by day. . . . . Cutworms

Good control for the *strawberry weevil* or "clipper" is to use DDT dust. Two applications are made before picking, when there is reason to expect an outbreak of the pest, first when the flower buds begin to push out of the crown, and then about 10 days later or just before the buds begin to open. DDT dust, if mixed with sulfur, will also help control red spider. DDT treatment must be stopped some time before picking starts. Planting near rubbish or trash should be avoided. (See also under Imperfect Varieties, Mulching, and Burning Over the Beds.)

For *strawberry leaf beetle* good control, as soon as the beetles are found feeding on the leaves, is to spray thoroughly with lead arsenate* five pounds in 100 gallons of Bordeaux mixture.

For control of *spittlebugs* use a DDT spray powder at one pound actual DDT in Bordeaux, to be completed by the time the first blossoms show.

Good control for the *strawberry root weevils* of the West is as follows. In late summer lift and burn all infested plants. Plow the fields and cultivate frequently for four weeks. Practice proper crop rotation. Plant potatoes before strawberries. Use poison bait around the plants, at the rate of 60–100 pounds per acre per application for gray weevils during April in Oregon, and for black weevils about the time of the second picking. The poison bait is made up as follows: Bran (or dried apple waste), 50 pounds; sugar, 10 pounds; calcium arsenate, five pounds; water, five gallons. Four ounces of sodium fluosilicate and $2\frac{1}{2}$ gallons molasses (to $3\frac{3}{4}$ gallons water) may be substituted for calcium arsenate and sugar respectively. The bran and the poison are mixed thoroughly, and the

* For chewing insects in general, DDT or rotenone may be substituted for the poisons mentioned in the basic formulas.

same procedure is followed in mixing the water and molasses. Care should be taken that the poison bait falls to the ground close to the crowns, instead of on the growing foliage and tender stems, though in actual practice the bait is often dropped into the center of each plant.

Control for the *strawberry leaf roller* is to dust with a fluorine material (one part to two parts talc and two parts flour) beginning when the tiny larvae first appear and repeating at weekly intervals for three or four weeks. If an application is needed when the berries are more than half grown or are ripening, use a summer oil at a strength of $1\frac{1}{2}$ per cent with nicotine sulphate at the rate of one part to 1,200 parts water; or use derris at recommended strengths to avoid fluorine residue. Fluorine treatments may be resumed if the second brood of larvae appears after harvest. Mowing and burning the foliage after the crop is picked is helpful. New plantings should be set as far as possible from old ones and dusted or sprayed as soon as the plants are well established. A good spray is lead arsenate four pounds in 6-8-100 Bordeaux applied just before the blossoms open. It is helpful to pinch folded leaves to kill the worms when setting out infested new plants.

White grubs are the larvae of May-beetles or June-bugs. They feed in the ground for two or three years before changing into adults. They are plentiful in sod land, particularly on light soils; they may hibernate over winter in corn stubble and then migrate into the planting. The larvae feed on the roots and either kill or seriously injure the strawberry plants they infest. Sod land may be prepared by growing for at least two years before planting strawberries, such crops as beans, peas, buckwheat, or pure stands of clover, all of which are more distasteful to the grubs. An even better plan is to cultivate the land for at least two years before planting strawberries. An application, just before planting, of one pound of lead arsenate to 100 square feet is a fairly successful control. But, the expense of the material may be too great, except in cases of emergency, or localized infestation of the planting. Chickens or hogs will destroy grubs if allowed access to the land soon after old sod is broken up.

Cutworms often weaken or kill plants by attacking the succulent parts. They are usually worse in plantings that have been in sod; such land, therefore, should be broken well in advance of planting. Fall plowing, and leaving the land in the "rough" over winter till spring planting, is helpful. The cutworms are likely to be found coiled up just below the surface of the

soil. Poisoned bran is a fairly effective control. It is made with 20 pounds bran, 1½ pounds calcium arsenate, one quart molasses, and 2–2½ gallons water. The bran and poison are mixed when dry and then stirred into the molasses-water solution. The mixture is spread thinly, after sundown, on the soil a week before planting or as soon as cutworm injury is noticed.

One means of reducing *strawberry crown moth* infestation is to top the beds directly after harvest, leaving several rows untopped. The moths on emergence will concentrate most of their eggs on the untopped plants; these plants should be plowed up and destroyed after mid-August in Oregon. The wings of the adults are so small that they cannot fly far and egg-laying is thus restricted to limited areas. New beds should be located at least 300 yards from an old bed. Plants for new beds should be dug early in the spring (no later than March 1 in Kentucky or Arkansas). In such areas, the female crown borer adults begin to lay eggs in the crowns of strawberry plants about the middle of, or late in, March. Therefore, if plants are taken from an old bed and set in April, the new bed may be infested from the beginning. Whenever temperature and other conditions permit, new beds should be started early in March or even in February in Arkansas. If early spring temperatures are not too low, such beds make good progress and by late June or early July, when crown borers, if present, begin to inflict visible damage, the plants will have numerous runners properly rooted. Such early planting is especially desirable where a new bed must be placed near an old bed. A control when setting new fields is to fumigate the plants with methyl bromide. This pest is more serious in regions with mild winters.

Immersion in water heated to 110° F. for 30 minutes frees the plants of the *strawberry crown mite* (cyclamen mite), and aphids, without injury to the plants. The plants should be placed loosely in the water as packed and tied bundles prevent an even penetration of the heat.

Red spider-mite can be controlled by spraying with a 1½ per cent highly refined summer-oil emulsion. The plants should not be allowed to suffer for water. (See also under *strawberry weevil* control.)

Key to the More Important Strawberry Diseases

1. Foliage diseases caused by fungi.
   (a) Spots first purplish, but later, as the affected tissues are killed by the fungus, their centers

pale to tan and gray and finally to almost white, surrounded by a purplish border.... Leaf spot

(b) Spots dark purplish, about 1/4 inch diameter, without white centers..... Leaf scorch

(c) Spots large, 1/4 to one inch across, red to brown surrounded by a purplish border.... Leaf blight

(d) Leaves curled upward. Lower surface exposed and with white mildewy growth..... Powdery mildew

2. Virus diseases. Yellowing or mottling, distortion and spotting of leaves, and dwarfing of the entire affected plants. Present in a serious way only west of the Rocky Mountains.

(a) Leaves tend to lie flat on the ground and the petioles are short, giving the plant a dwarfed appearance. Some leaves are wrinkled or distorted, mottled lighter green or yellow, veins become cleared or yellow and translucent. Faint yellowing spots or clearings ("stippling") in the leaves, especially of pin-head size on the youngest central leaf..... Crinkle

(b) Plants somewhat yellow and dwarfed due to shorter petioles and smaller leaves. Affected leaves tend to lose their pointed tips and may be cupped upward; centers dull green and edges yellow. Often one leaflet smaller than other two, and the youngest central leaf twisted or the leaflets curled..... Yellows or xanthosis

3. Noninfectious leaf variegation, mottling and streaking with yellow and green..... June yellows

4. Dwarf, or crimp, caused by nematodes

(a) Favored by high summer temperatures and primarily a disease of the South..... Summer dwarf

(b) Appears primarily in early spring..... Spring dwarf

5. Root diseases

(a) Early-spring stunting or dwarfing and wilting and dying of the older leaves. The new spring leaves on badly infected plants are

small, have short petioles, and are slightly bluish. In dug up plants the small fibrous roots are discolored, or have disappeared leaving only the rattail large roots. Central part of the large roots is dark red. (The reddening of the interior may be seen by splitting the root with a knife blade or by stripping off the outer portion of the root with the thumb nail)..... Red stele

(b) Prevalent in the South. Nematode galls or enlargements, especially at the tips of the smaller roots..... Root knot

(c) The most pronounced symptoms are usually observed when the berries are about half grown. The diseased plants wilt, turn yellow and dry up. The roots turn black, with few if any healthy lateral roots..... Root rot

6. Fruit rots and other defects

A. Field

(a) First appears as a light-brown, rather soft spot. Berries dry out and become firm, tough, of a uniform color throughout, and covered by a gray powder, or dusty-appearing fungus growth. More common in the cooler areas..... Gray mold rot

(b) Slightly sunken tan-colored areas develop on the side of the berry. The rot extends into the pulp so that the rotten portion forms a cone with its base at the surface of the berry. Important in the South... Tan rot

(c) Affected berries one-sided and with a hard brown rot separated from the sound portion of the berry by a distinct line. A small quantity of soil usually adheres to the decayed spot. Important in the South Hard rot

(d) Berries taste bitter. Affected parts are

brown. Diseased portion not easily removed. Important in the South..... Leather rot

B. In transit and on the market

(a) Berry collapses and much juice is lost in transit and on the market..... Leak

(b) Black spots about ¼ inch across surrounding the seeds; associated with leaf spot..... Black seed

(c) Dead, black caps giving berries an unattractive appearance; associated with common mold fungi, including the fungus-causing gray mold, leaf blight, and other semiprophytic fungi..... Dead caps

Leaf spot, *leaf scorch*, and *leaf blight* are widely distributed, and are often considered by the novice as different stages of the same disease. In spite of the wide occurrence of foliage diseases, spraying for their control with Bordeaux mixture is not generally practiced except in a few districts. In the Hammond, La., district, where spraying is regularly practiced, the first application is made early in January and is repeated at 10-day intervals until early in March. This schedule requires about six applications for the season. In North Carolina some spraying is done, and it is considered profitable, not only to preserve the foliage but also because berries from sprayed fields show less rot, are more attractive because of their greener caps, and are free of black-seed. Spraying has tended to prolong the harvest season, thereby increasing yields in some cases. In North Carolina spraying begins during late February or early March, when the first berries are about half their mature size. In the north, Premier is much more resistant than Gibson and many other varieties.

Dusting with 15–85 copper-lime, beginning when the fruit buds are expanding in the cluster and giving several applications at 10-day intervals is helpful when it is necessary to provide control for *powdery mildew*. In this disease, the leaves curl upward and the under surface is covered with a white powdery fungous growth.

The most promising method for reducing losses from *crinkle* and *yellows* in the Pacific coast sections is to grow under rigid State regulations

and supervision, and preferably in isolated places where aphids are not abundant, all plants intended for sale.

June yellows increased in significance with the introduction of Blakemore. Affected plants do not recover but may live for several seasons. All runner plants originating from a yellow plant show variegation in some degree. There is no known cure, other than to use yellow-resistant strains.

The most common method of spread of *dwarf*, or *crimp*, due to nematodes, is through the runner plants. The diseases are also spread by heavy rains that flood a field for several hours. Plants in low portions of the fields or in depressions are apt to become infected in this manner, provided there are diseased plants at higher levels in the field. Some good is done by roguing diseased plants when hoeing and weeding. Infected plants that are cut out should be removed from the field, as the nematodes may remain alive but dormant in dried plants and revive even after a considerable time if the plants become wet.

After *red stele* is once established in a planting there is no known means of effecting a cure. Disease-free plants should be obtained for new plant-

Strawberry roots. (*Left*) Nearly all healthy and many fibers. (*Center*) Some showing root-rot or black root, not enough fibrous roots. (*Right*) Nearly all roots showing root-rot. (Courtesy, Hort. Exp. Sta., Vineland, Ontario.)

ings. Spores that form within the red center of diseased roots will live for a long time in the dead roots and in the soil. Therefore, it is not advisable to replant a field to strawberries for at least three or four years after it has once grown a crop of diseased plants. There are resistant varieties, e.g., Sparkle, Pathfinder, Aberdeen, and Temple.

Southern growers can avoid trouble with root knot by establishing new fields with nematode-free plants on recently cleared land. If new soil is not available, then a field should be selected that for two or three years in succession has grown crops highly resistant or immune to the root knot nematode, e.g., corn, barley, oats, sorghum, Natal grass, velvetbean, cowpea (Brabham and Iron varieties), and Laredo soybean.

In *black root rot* wilting and dying of plants occurs at fruiting time. The roots are discolored, and fibrous roots are lacking. No complete control has been devised. The following precautions, however, should do much to reduce the losses: set out only vigorous plants with healthy roots; get these, if possible, from a planting free from black root; plant as soon as practicable after digging; select a well-drained site; rotate crops so that strawberries are not set in the same soil oftener than once in five years (soybeans preceding strawberries is beneficial in northern regions); follow cultural practices which tend to produce strong vigorous plants, such as the plowing under of cover crops, the judicious use of commercial fertilizers, and careful mulching.

3. Bramble-fruit Culture

THE INDUSTRY, REGIONS, AND DISTRICTS

THE BRAMBLE-FRUIT industry is classified into regions and districts for (a) the red raspberry, (b) the black raspberry, (c) the purple raspberry, (d) the blackberry and dewberry, including kinds like the Young and Boysen, and (e) the Logan. Probably 60 to 75 per cent of the raspberries in the United States, and nearly 100 per cent in Canada, are red raspberries; most of the remainder are blacks, and a low percentage are purples.

The total acreage of raspberries in the United States is about 60,000 acres,* and the production is in the neighborhood of 60,000,000 quarts. Corresponding figures for blackberries and dewberries are 40,000 acres and 50,000,000 quarts. The production of 12½ million quarts of reds in Canada gives a return of over $3,000,000.

Red Raspberry Regions and Districts

MICHIGAN. In Berrien and Van Buren Counties, though about two thirds of the more than 5,000 acres in this southwestern district consists of black varieties, the red is extensively grown. A large part of the crop is absorbed by local canneries, but mostly the berries are shipped by truck, and to some extent by boat, to Chicago and other fresh fruit markets. Benton Harbor and South Haven are leading points.

Another important area is in Manistee County and in adjacent Mason County. The main plantings are near Onekama.

The newest development is in the northern part of the lower peninsula,

* More exact figures can be obtained from Census reports and market releases.

particularly in Cheboygan County, where there are over 1,000 acres of reds. Some of the crop is sold for canning but most of it is shipped in refrigerator cars to Detroit and other cities. The main centers are Cheboygan and Wolverine.

NEW JERSEY. One section, the Hammonton district in southern New Jersey, contains probably 1,000 acres of Ranere in a space less than 10 miles square. The Ranere originated there and does particularly well on the light, sandy soil. Growers of foreign extraction with large families do most of the picking at an expense so low that the variety can be grown at a profit, including the fall crop.

NEW YORK. Large plantings occur in Erie and Chautauqua Counties, particularly near Brant and North Collins. The Hudson Valley formerly had extensive plantings, but, as disease destroyed the plantings, they were largely replaced by other crops. The Hudson Valley is coming back and with the newer varieties and knowledge of virus diseases is regaining some of its former greatness as a raspberry area.

OHIO. Though Ohio ranks among the first ten states in red raspberry production, the plantings are scattered more or less generally throughout the state for local consumption rather than in concentrated districts. The leading section borders Lake Erie. The black raspberry is much more extensively grown than the red.

ILLINOIS. Commercial culture is mostly in the counties in the extreme north and south, along the Mississippi river from Rock Island to Adams, and through central Illinois from Sangamon to Bureau Counties.

KENTUCKY AND TENNESSEE. The growing of reds, particularly Latham, has been tried as an industry in southwestern Kentucky, centering at Paducah. Growers in the general section of Portland, Mitchellville, and Westmoreland, Tennessee, and across the border line to Franklin, Woodburn, and Bowling Green, Kentucky, had delivered in the spring of 1933 a solid carlot of plants, chiefly Latham and Chief, and set several hundred acres. (See also later, Van Fleet.)

MISSISSIPPI. About 200 acres were set, chiefly Latham, near Amory, in the northeastern part of the state, in 1932, but the area proved to be too far south for successful culture of this variety.

ARKANSAS. Under a development scheme about 500 acres, mostly Latham and Chief, were planted in the Crowley Ridge section, centering at Wynne, in the east-central part of the state. In 1932, considerable

planting was done around Bastrop, La., near the Arkansas-Louisiana line. There is a small acreage of reds in northwest Arkansas. In general, though, Arkansas is too far south to grow raspberries commercially.

NORTH CAROLINA. Some reds, e.g., Latham, are grown in the western part. (See also Dixie variety.)

MINNESOTA. The red raspberry is one of the major fruits in Minnesota—the "home" of the Latham and the Chief. The main production is in Hennepin County near Minneapolis and St. Paul. Hopkins is the largest single section that is growing reds for the Twin City market, and produces about 60 per cent of the commercial crop.

COLORADO. Red raspberries are produced in Colorado in an environment which differs from that of other producing sections in three important ways: they are grown under irrigation; mostly the canes are laid down and covered with soil for winter protection; and, they are grown at elevations of 4,000–7,000 feet. There are two commercial districts: from Fort Collins, Larimer County, southward to Denver and its suburbs; and, in Mesa and adjoining counties in the western part of the state.

WASHINGTON. Most of the red raspberry acreage (an extensive one) occurs in the Puget Sound region in the western part of the state and is centralized largely in the Puyallup and White River valleys, around Puyallup and Summer, both in Pierce County. Snohomish, Whatcom, Thurston, and King Counties in western Washington have large plantings. A smaller area occurs in Clark County in southwestern Washington, across the Columbia River from the northern part of the area in western Oregon. There is also a small area in eastern Washington.

OREGON. Multnomah (1,000 acres), Clackamas (500 acres), Linn (200 acres), and Washington (100 acres), in the Willamette Valley, are the leading counties, but some reds are grown in most counties. Red raspberries ranked second among the small-fruit crops for many years but by 1944 this small-fruit crop had fallen to third place in value of marketings, being exceeded by strawberries and boysen-youngberries. In acreage and production it has fallen to fourth place, being exceeded in this by black raspberries also.

CALIFORNIA. Extensive shipments are made from the Santa Clara Valley. The three leading areas are just south of San Francisco, near Los Angeles, and near Sacramento.

CANADA. For many years, Ontario ranked far in the lead but production

in British Columbia has caught up and, in fact, in some years exceeds that of Ontario, being about 6,000,000 quarts in each depending on the year whether it is higher or lower than the figure given.

The leading raspberry areas in Ontario are much the same as the ones set forth earlier for the strawberry. The industry in British Columbia centers in the Fraser Valley, near Vancouver, and on Vancouver Island, near Victoria. To a small extent, reds are produced in New Brunswick (50,000 quarts) and Nova Scotia (75,000 quarts). In Quebec (1,000,000 quarts), the production centers near Montreal. The acreage in the Prairie Provinces is increasing.

Black Raspberry Regions and Districts

MICHIGAN. Southwestern Michigan, especially Berrien County, is one of the chief black raspberry areas in America. Much of the crop is taken by canners, and large quantities are trucked to nearby markets.

NEW YORK. Erie and Chautauqua Counties are leading sections, particularly near Brant and North Collins. In fact, black raspberry growing in this district is probably more concentrated than anywhere else in the country. Blackcaps are grown in Ontario County on the west side of Canandaigua Lake, e.g., the Bristol area, and in Yates County, 15–20 miles south and southeast of Geneva, centering at Dundee. A third area is in Oswego, Wayne, and Monroe Counties, south of Lake Ontario. Another area is in the Hudson River Valley.

OHIO. Ohio ranks third in the black raspberry industry. The leading section borders Lake Erie in the counties of Ashtabula, Lake, Cuyahoga, Lorain, Erie, and Sandusky. Cleveland is the chief market for berries from this district, though in Sandusky County, where production centers around Clyde, some of the crop is sent to Toledo and Detroit just ahead of the Michigan crop. Important plantings are found in southeastern Ohio in Lawrence and Scioto Counties, in east-central Ohio in Columbiana and Portage Counties, in southwestern Ohio in Hamilton and Belmont Counties near Cincinnati, in south-central Ohio in Ross and Fairfield Counties, and in west-central Ohio near Dayton.

PENNSYLVANIA. The chief acreage is in Erie County in northwestern Pennsylvania. Other areas are in the southeastern part and in counties near Pittsburgh in the southwestern part.

MISSOURI. The largest area is in St. Louis County. There is also a dis-

trict near Kansas City in Jackson County, and a smaller one in Buchanan County in northwestern Missouri.

MARYLAND. Washington County is the chief area, the berries being marketed chiefly in Pittsburgh. The main commercial area is found on or near the west slope of South Mountain, which is a continuation of the Blue Ridge Mountains of Virginia. Some plantings are found almost from Harper's Ferry on the south to the Pennsylvania line on the north. The heaviest plantings extend from Gapland on the south to Bagtown on the north, with Boonsboro about the center. Another important area occurs on the mountain east and southeast of Smithsburg.

OREGON. Yamhill (800 acres), Washington (600 acres), Clackamas (500 acres), Linn (300 acres), Marion (150 acres), and Multnomah (100 acres), in the Willamette Valley, have most of the acreage. Black raspberries are grown in Yamhill and Washington Counties mainly as a "filler" crop or intercrop in newly planted walnuts and filberts. They are also well adapted to the hill-land soils of these counties.

PURPLE RASPBERRY REGIONS AND DISTRICTS

Purple raspberries are grown to some extent in western New York, western Michigan, Missouri, Ohio, and Pennsylvania. At one time, especially in western New York, purple raspberries were grown extensively for evaporation or drying. In New York, purples are now grown for fresh fruit and canning in Erie and Chautauqua Counties (particularly near Brant and North Collins), in Wayne County, and in Oswego County.

BLACKBERRY AND DEWBERRY REGIONS AND DISTRICTS

TEXAS. Texas, with about 6,500 acres, ranks first in acreage of blackberries and dewberries in America. The industry centers in the Northeast Timber Country, the Black Prairie, and the East and West Timber sections, which are natural geographic divisions. About a third of the crop is produced near Tyler, Smith County, in the Northeast Timber Country. A wide range of types and varieties are grown.

OKLAHOMA. Oklahoma, with about 3,500 acres, ranks well up in acreage of blackberries and dewberries. The largest acreage is near Oklahoma City in the central Pottawatomie County, where there are about 650 acres, chiefly Lawton. An interesting commercial area is in the northwestern Major County. This is high plains country which is devoted

mainly to wheat, but there is some splendid berry soil in the river bottom which is sandy and sub-irrigated by the underflow from the river. There are, in the western part of this county, several plantings that run as high as 80 acres. It is entirely a local-market industry, as wheat farmers come in from miles around, some of them picking on shares and some buying the fruit outright. The Austin dewberry has been extensively planted, but is giving way to the Boysen which, in turn, is favored over the Young.

ARKANSAS. There are about 2,500 acres of blackberries in the state, the chief acreage being in the Ozark region. Large plantings occur near De Queen in Sevier County in the southwest district. The Boysen winter-kills in the higher, northern sections, but does well in the southern and eastern. It does not bear as heavily as Young. A selection of Young, the Lavaca berry, is popular.

MISSOURI. The total acreage is about 1,500 acres. In the eastern section, the largest acreage is in Jefferson County, southwest of St. Louis. Other counties in this area are St. Louis, St. Francois, and Franklin. In central Missouri, near Jefferson City, a number of counties (Cole, Maries, Moniteau, Osage, and Phelps) have from 25–100 acres each. A third area is in western Missouri near Kansas City and south of it. A fourth area is in the south as part of the Ozark region.

TENNESSEE. Several million pounds of blackberries are put up in the frozen-pack each year, and the Boysen and Young are widely grown.

KENTUCKY. The chief center is in the southeast corner in Pike and adjoining counties.

WEST VIRGINIA. The southwest area leads, in Wyoming, Raleigh, Summers, and adjoining counties. Slightly to the north, but a part of the same area, there is an acreage in Roane County.

MICHIGAN. The total for the state is about 2,000 acres. The chief acreage is in Berrien County. Erect blackberries provide most of the crop, but some dewberries are grown near Benton Harbor.

OHIO. Four districts are as follows: Lake Erie—Cuyahoga, Lorain, and Frie Counties, near Cleveland; south-central—Fairfield, Ross, and Franklin Counties, near Columbus; southwest—Hamilton and Clermont Counties, near Cincinnati; and southern—Lawrence and Scioto Counties. In Ohio, as in many other states, large areas of "wild" blackberries occur.

NEW JERSEY. Most of the acreage is in southern New Jersey. The industry centers at Hammonton, which is in Atlantic County, and reaches

into Camden, Cumberland, and Gloucester Counties. The plantings are chiefly in the hands of growers of Italian extraction. A small area occurs in Monmouth County in eastern New Jersey.

PENNSYLVANIA. The chief districts are: west—near Pittsburgh, in Westmoreland, Beaver, and Fayette Counties; north—in Erie County, a westward continuation of the area in Erie and Chautauqua Counties, New York; southeast—Lancaster and York Counties.

NEW YORK. The three leading areas, growing mostly erect blackberries, are: western—near Buffalo, in Erie and Chautauqua Counties; north-central—near Rochester and Oswego, in Monroe, Onondago, Oswego, and Wayne Counties; eastern—in Albany, Columbia, Renssalaer, Saratoga, and Schenectady Counties.

NORTH CAROLINA. The chief acreage is in Moore County near Cameron, the heaviest shipping point of dewberries in the United States. There are about 1,500 acres of blackberries and dewberries in the state.

ILLINOIS. More blackberries are grown in the central and southern sections than in other sections. Some large acreages occur in the central counties from Sangamon to Tazewell and in the southwestern counties from Washington to Madison. The southwestern area is near St. Louis and is an eastward continuation of the area in eastern Missouri. The state acreage is about 1,000 acres.

INDIANA. The chief acreage is in Floyd and Clark Counties in southeastern Indiana.

KANSAS. The chief acreage is near Wathena in Doniphan County, which is across the Missouri River from St. Joseph, Mo. A little to the south along the river there is another area in Wyandotte and other counties near Kansas City.

WASHINGTON. The acreage, about 2,000 acres, chiefly Evergreen, Boysen, and Young types, is mostly in western Washington. Pierce County leads in production.

OREGON. The Evergreen type grows wild along fences and streams throughout the western section. Of the estimated 600 cultivated acres harvested in 1944, Marion County had 300 acres or 44 per cent and Multnomah 175 acres or 26 per cent. These counties are in the Willamette Valley, where also is found about 90 per cent of the Boysen and Young acreage of 2,500 acres. These types are also extensively grown in southern Oregon and some other areas. In 1944, Marion County had 735 acres or

about 29 per cent of the state's acreage, Multnomah 19 per cent, Clackamas 13 per cent, and Washington County 12 per cent. Commercial production began in 1930. In 1936, only 1,000 acres were harvested, mostly of the Young type. The Boysen subsequently has taken the lead.

CALIFORNIA. In 1946, the state acreage reached a peak of 6,000 acres, or twice that of five years earlier. The commercial acreage is roughly divided into these three areas:[25] Central Coast, Southern, and Central Valley.

The Central Coast area extends from Sonoma County, which is 50 miles north of San Francisco, to Monterey County, which is 75 miles south, and inland about 40 miles to include several coastal valleys. This is a relatively cool area, where production extends from early June through August. Here the Boysen produces as much as 10 tons per acre.

Southern California comprises an area including districts of diverse climates, most of which, however, are characterized by warm winters and saline or alkaline soils. Symptoms of delayed foliation appear in many plantings after winters of insufficient chilling weather. In this area, four tons per acre is a good yield for the Boysen.

In the Central Valley, in contrast with the other two areas, the summers are hot and the winters are cold. The greatest expansion of the industry in the state over pre-war levels occurred in this area. Most of the crop is sold to frozen-food companies. In this area there are thousands of acres of peaches. Peach thinning, berry picking, and peach picking follow one another in sequence. It is, therefore, a distinct advantage to include berries in the production scheme so that growers can provide employment for their harvest help from the start of the peach-thinning season to the end of the peach harvest. In general, the yields in this area have been equal to those of Southern California, but a maximum of 8–10 tons per acre have been produced by a few growers through intensive culture. The production period extends from late in May to early June.

CANADA. The chief acreages are in the Niagara Peninsula in Ontario, and in the Lower Mainland district in British Columbia.

LOGANBERRY REGIONS

Culture of the loganberry is largely restricted to certain areas in California, Oregon, and Washington, especially west of the Cascade and Sierra ranges in the United States, and to Vancouver Island and the Coast

sections of British Columbia, in Canada. The largest centers are the Central Coast region of California, the Willamette Valley of Oregon, and Victoria, B. C. In Washington the canes suffer more or less from winter injury except in the Lower Columbia River Valley and in very protected places in the Puget Sound region. The annual production in British Columbia is about 1,500,000 quarts, from about 450 acres, much of which is made into "wine."

DEVELOPMENT OF VARIETIES*

Development of Red Raspberry Varieties

The history of reds in America involves: native or wild raspberries (*R. strigosus*); introductions from Europe (*R. idaeus*); and, hybrids originating in this country.

Wild raspberries, in early days, supplied the demand. As population increased and cities developed, need for improvement of reds arose. In most varieties which assumed leading rank in the East and which originated in America *R. strigosus* predominated, largely because of hardiness. European red raspberries, however, have been associated with the development of red raspberries in this country, and indications of *R. idaeus* blood appear in most important American varieties of today.

Red Antwerp, a European variety, was known in America in 1806. Hudson River Antwerp, introduced in 1817 from Europe, was a leader in the Hudson Valley, N. Y., for about 25 years, and in 1878 14,700 bushels were shipped from Marlboro.[247]

Turner, supposedly a seedling of Red Antwerp, originated about 1850 in Illinois. For several decades it was highly prized.

Cuthbert was found near a bed of Hudson River Antwerp about 1865 and was disseminated about 1880. It soon became the leading variety and remained so for some 50 years. Loudon, a cross of Turner x Cuthbert, originated about 1884, assumed prominence for a time, and then its popularity declined.

Marlboro, introduced in 1884, soon became the standard early red but is now little planted except in limited areas, as in Colorado. In some sections, as in New Jersey, Ranere became a leader. In many other regions,

* The origin of additional varieties is given under Characteristics, p. 233.

particularly in the central-west, King, which was introduced in 1892, became the chief early variety. Perfection, discovered about 1890, was important in the Hudson Valley until 1922 when most of the plantings were removed because of mosaic.

Herbert, which originated in 1887 in the garden of R. B. Whyte, Ottawa, is a pioneer among the varieties originating in Canada. Other varieties which have since originated in Canada are: Newman, Viking, Adams, Brighton, Count, Ottawa, Gatineau, Madawaska, Rideau, and Trent.

Latham, which originated in 1908 from a cross of King x Loudon, was first distributed for trial in 1914 and is now the leading variety in America. In 1920, it was named in honor of A. W. Latham, who for 29 years was secretary of the Minnesota Horticultural Society. The Latham furnishes a good example of the value of fruit breeding work by state institutions. In one year alone, e.g., 1926, the income or wealth accruing to Minnesota from the Latham was more than adequate to cover the total cost of the state-supported fruit breeding experiments since the establishment of the first farm in 1878.[4]

Chief, a self-pollinated seedling of Latham, originated at the Minnesota State Fruit Breeding Farm. It is outstanding for hardiness.

Lloyd George, though not itself suitable in America, has been an outstanding parent in the development of improved varieties for this continent, and its use in breeding has given rise to varieties like Taylor, Marcy, Milton, Indian Summer, Washington, and Willamette.

Development of Black Raspberry Varieties (*Rubus occidentalis*)

In 1932 the first named American black raspberry appeared. It was called the Ohio Everbearing and was discovered by Nicholas Longworth, Cincinnati, Ohio. Until 1850, attempts were made without much success to propagate the black raspberry by division. In that year H. H. Doolittle used a tip-layering method, a noteworthy contribution. The Doolittle variety, which was associated with his name, became popular.

Souhegan, discovered in 1869 and introduced in 1881, next assumed prominence; later it shared popularity as an early sort with Tyler and Palmer. These varieties were superseded by Kansas, and, in turn, by Plum Farmer and New Logan. Ohio (distinct from Ohio Everbearing) originated in a bed of Doolittle plants and assumed prominence in the East for

evaporation purposes. McCormick (Mammoth Cluster) was introduced in 1867 and, as a late-midseason variety, assumed the lead until superseded by Gregg.

Cumberland, a midseason variety introduced in 1896, soon assumed the rank of leading variety. For more recent varieties, e.g., Dundee, Naples, Bristol, Evans, and Morrison, see later.

Development of Purple Raspberry Varieties (*R. neglectus*, a hybrid of black and red raspberries)

The Philadelphia variety, found in 1840, attracted attention in 1866 and led until 1880 (though Philadelphia was commonly regarded as a red raspberry, it seems proper to consider it with the purples). Shaffer originated about 1871 and was introduced in 1878. It, in turn, was superseded by Columbian which originated in 1888 and, like Cardinal, was introduced in 1891. (See also later under Varieties.)

Development of Blackberry, Dewberry, and Related Varieties

Erect Types. Dorchester, the first named blackberry, was discovered about 1840. Lawton was the second named, though it came under cultivation first. Wilson, discovered about 1854, became highly prized. Kittatinny appeared about 1865 to share popularity with Wilson and was a standard for nearly 50 years. Snyder, found in 1851, was a standard for many years but its history follows, rather than parallels, that of the two previously mentioned varieties. Taylor, introduced in 1867, was a late variety. Other old varieties are Agawam, Ancient Briton, Early Harvest, Mersereau, Rathrun, and Ward.

Eldorado, which originated about 1880, superseded other varieties and is the leader at present. An improvement over Eldorado is much to be desired. Blowers showed some promise of superseding it, but susceptibility to orange rust is a serious drawback.

The common or copsy highbush blackberry of the north is *Rubus alleghoniensis*, and includes Eldorado, Taylor, Agawam, Ancient Briton, Early King, Erie, Snyder, and Wilson. In the field highbush blueberries (*arguti*) are such as: *R. ostryifolius*, e.g., Blowers, Kittatinny, Macatawba, Ohmer, Ward, Watt, and Early Harvest; and *R. louisianus*, Crystal White and Iceberg; *R. frondosus*, Lawton.

TRAILING TYPES. Oregon Evergreen was probably the first trailing blackberry to be cultivated in America. It was introduced to Oregon early in the history of the state from the South Sea Islands, where it had probably been brought from Europe. The cultivated Evergreen plants have almost all been propagated from wild plants; consequently, cultivated plantings are made up of propagations from hundreds of individual seedlings.[161] Most of these were probably taken without specific reference to their fruiting habits. Notwithstanding this, they are remarkably uniform. In a few instances, growers have propagated from selected wild bushes.

Auginbaugh, propagated about 1875, was one of the first Pacific Coast forms.

The native western or "trailing" blackberry has the finest flavor of any blackberry. It is a native in the area west of the Cascade Mountains from northern California to British Columbia. Though selections from the "wild" have occasionally been grown under cultivation, they have not been very productive. One reason for this is that the staminate (male) and pistillate (female) flowers are borne on separate plants and the selected plants bear female flowers only. Plants with perfect blossoms are rarely found in the natural state. Other reasons[169] for the low yields from native selections are the small size of the fruit and the susceptibility under cultivation to the Septoria leaf and cane spot. (See Pacific and Cascade varieties, both of which are perfect flowered.)

Blackberries of the trailing type are not hardy at temperatures of −10° F. or lower.

LOGANBERRY. According to reports by the originator, J. H. Logan, Santa Cruz, Calif., in 1881 he sowed seed of the Auginbaugh, a very vigorous pistillate selection of the wild *Rubus*, but having larger, darker leaves, and fruit similar to the Logan in shape.[171] This plant grew in Logan's garden near the Texas Early blackberry and a red raspberry similar to Red Antwerp. The resultant seedlings, with one exception (the Loganberry) were said to be similar in appearance. Most of the seedlings were considered crosses of the Auginbaugh and Texas Early blackberries. The Mammoth blackberry was selected from this first lot or from later ones and was similar to the majority of the seedlings. Seedlings other than Logan and Mammoth were distributed but proved to be pistillate and so were

later discarded. The Logan was perfect-flowered and red-fruited and was considered a cross of Auginbaugh blackberry and Red Antwerp raspberry. Certain studies[148,171] seemed to establish that, instead of being a hybrid, this fruit is a red-fruited perfect-flowered sport of a Pacific Coast trailing blackberry.

Further information on the subject has become available through the work of George F. Waldo,* U.S. Department of Agriculture, at Corvallis, Oregon. Crosses were made between the European red raspberry La France, which is a tetraploid, and several wild blackberries from the northern coast of California. The resulting seedlings were very suggestive of the Logan. There seems to be no doubt but that a direct cross was obtained because the fruit of many selections separated as a red raspberry and in almost every case the fruit color was an intermediate between red and black. The flavor and acidity was very similar to the Logan. In the case of the blackberry crosses with the Eldorado, plants were obtained with cane characteristics almost identical to that of Mammoth. The berries were always black but most of them had a flavor suggestive of the Eldorado and, in general, much superior to the flavor of the Mammoth.

The Thornless Logan is an important commercial variety and is replacing the thorny type.

Dewberry, Ness, Young, and Boysen. Bartel, the first printed record of which appeared in 1875, originated in Illinois and was the first dewberry to receive wide recognition. Lucretia, however, which was brought to general notice about 1886, was the first to receive the approval of growers.

In 1913, Helge Ness crossed a wild dewberry of Texas with a red raspberry. The second generation of this cross was fully fertile and a later selection was introduced as Nessberry. This has a delightful flavor and thrives well in East Texas, but it proved unpopular because of poor picking quality and difficulty in propagation. Ness later crossed his hybrid back to the wild dewberry. Selections of this backcross were self-pollinated by S. H. Yarnell in the early 1930's. Three selections, Earli-Ness, Big-Ness, and Regal-Ness, proved to be unusually early and well adapted to East Texas.

* Correspondence, Aug. 19, 1947.

The Young or youngberry and the Boysen or boysenberry (see later for history) are widely planted in the Southwest, South, California, and Pacific Northwest. They are not suitable in northern regions. Furthermore, many nurserymen have found that they can produce large quantities of the plants very cheaply, and so this type of fruit has been pushed for planting in areas where it is not suitable.

CHARACTERISTICS OF BRAMBLE-FRUIT VARIETIES

Leading Red Raspberry Varieties

Chief. One of the hardiest of red raspberries for the northern limits. Highly productive. Fruit rather small. Ripens fairly early. Origin—Minnesota Fruit Breeding Farm; self-pollinated seedling of Latham.

Cuthbert. For many years the leading midseason variety throughout the country, and still holding this rank in parts of the Pacific Northwest, Michigan, and in a few other areas, but it has lost greatly in importance. When well grown, it is superior to most other varieties in dessert, canning, and freezing qualities. Not so uniform in color as could be desired. Rich flavor. Comparatively low yielding and slow to pick. Origin—chance seedling found by Thos. Cuthbert, Riverdale (now part of New York City), about 1865.

Dixie. Adapted to regions, e.g., North Carolina, which are too far south for successful red-raspberry culture with the varieties usually grown in northern areas. Plants often producing lateral canes 12–15 feet long. Suckers sparingly; propagated by tip layers. Berries bright red, tart or acid, soft. Origin—Asiatic species *Rubus biflorus* x Latham at North Carolina Experiment Station in 1928; described in 1938.[518]

Indian Summer. Bears in early summer and in autumn. Ranks only fair for the early crop, the fruit being rather dark, crumbly, and soft, but compares favorably with Ranere as a fall crop, particularly when trellised in a narrow hedgerow or for the home garden. Origin—Experiment Station, Geneva, N. Y.; Seedling 1950 (Empire x Herbert) x Lloyd George in 1925; introduced in 1936.

June (Ontario). June is more widely distributed and of greater importance than Ontario of which commercial plantings are largely restricted to the Brant-North Collins sections in Erie County, N. Y. Earliness is one of its chief merits. It is about 10 days earlier than Latham and five days earlier than Chief. Does best on the heavier and more fertile soils. Origin—Experiment Station, Geneva, N. Y.

Latham. The most widely grown red in America as a whole. Ripens midseason, long picking season; highly productive; large fruit, comparatively rapid picking; prolific plant maker; hardy in the north. Fruit only fair in quality, tends to crumble under some conditions. Plant susceptible to mildew. Also, though highly tolerant of the virus diseases, it is a notorious offender when planted near blackcaps. Origin—see under Development of Varieties.

Madawaska. Same season as Viking but hardier in the colder regions. It is a good cropper and the fruit is medium to large in size, of fair quality but somewhat

acid. Round-conic in shape and moderately firm. A bit dark in color, probably useful as a jam berry. Origin—Central Experimental Farm, Ottawa, Ontario; Lloyd George x Newman 23.

MARCY. Berries notably large, long conic, midseason, mild flavor, medium red, bright if picked promptly but tending to become dark. Vigorous grower with heavy stocky canes that stand erect well and are highly tolerant of mosaic. Origin—Experiment Station, Geneva, N. Y.; Lloyd George x Newman in 1925; introduced in 1936.

MILTON. Berries large, long conic, firm, late. Plants tall, sturdy, increase rapidly by suckers, highly free from mosaic. Origin—Experiment Station, Geneva, N. Y.; Lloyd George x Newburgh in 1927; introduced in 1942.

MONROE. Berries firm, resemble Cuthbert in flavor but are more acid, larger, and almost a week earlier. Plants similar to Cuthbert in appearance, vigor, and habit of fruiting, but the leaves of Monroe are more wrinkled and the prickles are fewer and weaker. Origin—Experiment Station, Geneva, N. Y; Newman x Cuthbert in 1921.

NEWBURGH. Bushes low, spreading, much branched, until about three years old. Canes shorter than those of most reds, may bend to the ground and the berries be spoiled, hence the desirability of a trellis. Growers frequently fail to cut back the canes of this variety at the dormant pruning because they are shorter than those of other red raspberries. This is a mistake;[45] the canes should be cut back or they will bear more fruits than the plants can mature. The result will be small berries that may pick hard or even dry up without ripening, especially under drought conditions. Suckers freely. Ripens a few days earlier than Latham. Fruit large, very firm, less crumbly than Latham. Because of its freedom from mosaic it is outstanding for growing with black raspberries. Origin—Experiment Station, Geneva, N. Y; Newman x Herbert; introduced in 1929.

RANERE (St. Regis). Ripens early in summer and bears a light crop in the fall at the tips of the first-year canes. Extensively grown in New Jersey and in the coastal region of California. Elsewhere it is unsatisfactory, the fruit being small, poor in quality, and slow to pick. Origin—with a Mr. Ranere, in New Jersey.

TAYLOR. Berries long conic, large, maintain their size well, medium red color, good quality, ripen with Latham, free from crumbling. The berries do not cling to the bush as do those of Newburgh. Plants tall, vigorous, and productive, with sturdy canes which hold the fruit well off the ground. Rapid propagator. Canes covered with short, stubby purplish prickles which rasp rather than scratch. Origin—Experiment Station, Geneva, N. Y.; Newman x Lloyd George in 1925; named in honor of O. M. Taylor who for many years was a member of the staff there; introduced in 1935.

TRENT. A very fair to good grower. Yields moderately well. Fruit is of medium size, only moderately firm, fair quality, rather dark in color. Ripens a day or so before Viking. Shows some promise as a jam berry. Origin—Central Experimental Farm, Ottawa, Ont.; Newman 23 x Lloyd George.

VAN FLEET. Yellowish red fruit. Useful just south of the limits of successful red raspberry culture. Origin—A cross of a Chinese bramble x Cuthbert made in 1911 by Dr. W. Van Fleet, Chico, Calif.

Two patented varieties, viz., Tennessee Autumn red raspberry and Tennessee Luscious red raspberry, contain Van Fleet "blood." The former originated from

Seedling 181 (Latham x Van Fleet) x Lloyd George. The latter came from Lloyd George x Tenn. Sdlg. VV169 (Van Fleet x Viking); thus it is at least $^1/_2$ *R. idaeus*, $^1/_8$ *R. kuntzeanus*, and part American red raspberry (*R. strigosus*).*

VIKING. More uniform and slightly lighter in color than Cuthbert and does not crumble as does the Latham. Excellent quality. Canes vigorous, spineless. Origin—Horticultural Experiment Station, Vineland, Ont.; Cuthbert x Marlboro in 1914.

WASHINGTON. Does better in Pacific Coast regions, where it is heavily planted, than in the East. Berries late, moderately firm, sweet, medium red color. Origin—Western Experiment Station, Wash.; Cuthbert x Lloyd George; introduced in 1938.

WILLAMETTE. In western Oregon it is more productive, much firmer, and has been among the best varieties in frozen-pack tests, and in canning tests rated equal to Cuthbert. Origin—Oregon Experiment Station; Newburgh x Lloyd George in 1933; introduced in 1943.

LEADING YELLOW RASPBERRY VARIETIES

GOLDEN QUEEN. Except for color, it is much like Cuthbert. Unsatisfactory for commercial planting. Origin—with E. Stokes, Berlin, N. J., in 1852; Cuthbert parentage.

LEADING BLACK RASPBERRY VARIETIES

BRISTOL. Berries medium early (about a week before Naples or with Plum Farmer), large, firm, excellent quality. A moderate amount of bloom detracts somewhat from the glossiness of the berries, which, however, are sufficiently attractive for the market. The small size of the drupelets contributes to the attractiveness of the berries. Plants vigorous and productive, canes sturdy. Origin—Experiment Station, Geneva, N. Y.; Watson Prolific x Honeysweet in 1921; introduced in 1934.

CUMBERLAND. The best midseason black raspberry when well grown. The prime weakness is its susceptibility to virus diseases and anthracnose. Origin—with Davis Miller, Camp Hill, Pa.; introduced in 1896.

DUNDEE. Berries large, handsome, ripen midway between Bristol and Naples. The small drupelets contribute to the attractiveness of the fruit. The plants at their best are unusually vigorous and bear heavy crops. Endures mosaic fairly well. Origin—Experiment Station, Geneva, N. Y.; Smith No. 1 (a local seedling) x Palmer in 1910; introduced in 1927.

EVANS. Compared with Bristol, Evans is glossier, softer, more attractive, and a day or so earlier. The plants are not so vigorous and do not stand up quite as well as those of Bristol. Origin—Experiment Station, Geneva, N. Y.; Watson Prolific x Honeysweet. Introduced in 1936.

MORRISON. Fruit large, glossy black, late. Well liked at Girard, Pa., and adapted to the northern half of Ohio and near the fruit belt of the Great Lakes. Origin—first known to be grown by Fred Morris and his brother at Ashtabula,

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* Drain, B. D. Tennessee Autumn red raspberry. Tenn. Cir. 70. 1940. Tennessee Luscious red raspberry. Tenn. Cir. 92. 1945.

Ohio. About 100 plants were given to the truck driver, named Morrison, who hauled their berries to market. From this lot of plants commercial plantings were built up around Girard, Pa. Introduced by W. N. Scarff's Sons, New Carlisle, Ohio.

NAPLES. Fruit firm, handsome, late, possibly superior to Cumberland. Origin—Experiment Station, Geneva, N. Y.; Honeysweet x Rachel in 1921; introduced in 1932.

NEW LOGAN. Ripens earlier than Cumberland. Leading variety in the Clyde district in Ohio, but elsewhere it is less popular. Seems to be immune to leaf curl. Origin—Illinois; brought to Clyde, Ohio, about 1915.

PLUM FARMER. Ripens earlier than Cumberland. Season short. Not so good in quality nor so productive as Cumberland in the east. It is a leading variety in Oregon. Origin—found by E. J. Farmer, Pulaski, N. Y., in a shipment of raspberry plants from Ohio in 1892.

LEADING PURPLE RASPBERRY VARIETIES

COLUMBIAN. Long the leader in northern Midwest and Eastern regions. Highly productive. All stock of this variety seems to be uniformly affected with green mosaic, symptoms of which are very mild. It should not be grown near black raspberries or mosaic-susceptible red and purple varieties. Origin—with J. T. Thompson, Oneida, N. Y., in 1888; Cuthbert x Gregg.

CARDINAL. Leading variety in southern Midwest. Origin—with A. H. Griesa, Lawrence, Kans,. in 1888; seedling of Shaffer.

MARION. Berries very large, maintain their size well, roundish conic, with a slight tendency to crumble and also to cling to the plant (these characteristics necessitate care in picking), ripen about a week later than Sodus. Susceptible to orange rust. Origin—Experiment Station, Geneva, N. Y.; Bristol black raspberry x Sdlg. 2585 (a sister of Newburgh red raspberry); introduced in 1937.

POTOMAC. A fairly good variety. Origin—U.S. Dept. of Agriculture; Plum Farmer x Newman.

SODUS. Compared with Columbian, Sodus berries are larger, firmer, more attractive, less crumbly, more acid and not as good in fresh quality. Sodus plants are more vigorous, more drought resistant, and relatively free from mosaic. Fruiting laterals long. Origin - Experiment Station, Geneva, N. Y.; Dundee black raspberry x Newburgh red raspberry in 1927; introduced in 1935.

WEBSTER. Fruit medium size, midseason. Liked by growers in Erie County, N. Y., because of its yield, firmness, and because the berries are mostly on the outside of the plant and are easily reached. Origin—Experiment Station, Geneva, N. Y.; Smith No. 1 black raspberry x unknown purple in 1910; introduced in 1926.

LEADING BLACKBERRY, DEWBERRY, AND RELATED VARIETIES

ALFRED. Erect growth. About equal to Eldorado in most characteristics. Found by Geo. Stromer growing near a junction-station called Alfred in Michigan, in 1917.

AUSTIN. An early dewberry; softer than Lucretia. Origin—Texas

BLACK DIAMOND. Trailing growth. Grown chiefly in southern New Jersey in the East. Origin—Seedling of Oregon Evergreen or similar to it; with G. H. Liepe, Cologne, N. J.

BLOWERS. Erect growth. Less reliable, because of susceptibility to orange rust, but with larger fruit and more vigorous habit of growth than Eldorado. Origin—H W. Blowers, Westfield, N. Y., about 1888.

BOYSEN. This is a trailing variety that resembles the Young (there are thornless selections of each but they have not become popular). More vigorous than Young and with darker-green leaves. Ripens about 10 days later than Young. The large fruit (sometimes $1\frac{1}{2}$ inches long) is dark red (almost black), and is rather soft. Fruit with a distinct aroma, which the Young lacks. Fruit covered with a dusty bloom, whereas Young is shiny. There is also more of a distinct core in Boysen than in Young. Not quite as sweet as Young. Planted more extensively than any other bramble fruit in California where its high yield and quality as a fresh or frozen berry account for its importance. It produces a second crop in Southern California and in the Central Coast area, thereby extending the picking period there through August. Origin—with Rudolph Boysen, Anaheim, Calif.; Himalaya blackberry was the female parent. Introduced in 1935.

BRAINERD. Its desirable qualities are the vigor of plants (both top and root), their productiveness, their hardiness, and the large size and high quality of the fruit when fully ripe. Its weaknesses are: the large prickles (like the mother plant, Himalaya); a peculiar variegation of its leaves; lack of quality, like most eastern varieties, until fully ripe; susceptibility to orange rust in the eastern states; and a slight susceptibility to double-blossom in the southern states. Useful in the regions of the Pacific Coast States with hot summers.[178]

CAMERON. Dewberry. Promising in North Carolina. Origin—Young x Lucretia at North Carolina Experiment Station about 1930.

CASCADE. Trailing growth. Softer than Pacific and therefore not so attractive as that variety on the fresh-fruit market or in the can. Its dessert quality, however, is generally superior to the Pacific, and for jam and preserves it is unsurpassed. It is generally more productive than the Pacific. Origin—Oregon Experiment Station; Zielinski, (a selection of the trailing blackberry, found in 1926 by B. C. Zielinski, Salem, Ore.) x Logan; named and introduced in 1940.

CRANDALL (Macatawa). Trailing growth. Ripens early. Grown in southern California. Origin—Texas.

DALLAS. Trailing growth. Grown chiefly in Texas where it originated, and to a lesser extent in Oklahoma and Florida.

EARLY HARVEST. Erect growth. Extra early but otherwise possessing few merits. Fruit small. Highly susceptible to rust, which is a serious problem in the South where it is widely grown. Origin—found wild in Illinois before 1880.

ELDORADO (Stuart). Erect growth. Leading midseason variety, except in the extreme South and northern New England. When true-to-name, it is practically free of orange-rust. When this trouble occurs on Eldorado usually some other variety has been mixed in the planting. Origin—near Eldorado, Ohio, about 1882.

EVERGREEN. Trailing growth. Grown chiefly in Pacific Coast States and in southern New Jersey.

HIMALAYA (Theodor Reimers). Trailing growth. Late. Grown in California and to some extent in Oregon and Washington, South Carolina and Georgia, and in some other parts of the South. European origin; introduced by Luther Burbank about 1889.

LAWTON. Erect growth. Important in Texas. Origin—with Wm. Lawton, New Rochelle, N. Y., about 1848.

LOGANBERRY. Trailing growth. Red fruit. Grown chiefly in the Pacific Coast States. Not adapted to the East. Origin—see earlier.

LOWDEN. Erect growth. Vigorous. Does not seem to be susceptible to orange rust; also, it appears to be hardier than Eldorado as grown in Ontario. It yields equally as well and ripens several days earlier than that variety. Fruit large, excellent quality, and practically without a core. Origin—found about 1926 by Edward Lowden, Hamilton, Ont.; probably a seedling of Snyder.

LUCRETIA. Dewberry; trailing growth. Wider adaptability than most other dewberries but capricious in behavior. Berries large, long, firm, ripen about June 1 in North Carolina. Origin—found in West Virginia soon after the Civil War and brought to general notice about 1886. Introduced by B. F. Albaugh, Covington, Ohio.

MAMMOTH. Upright and trailing growth. Grown chiefly in California in the milder parts of the Pacific Coast States. Needs a pollinizer. Origin—California.

MAYES. Trailing growth. Resistant to drought and heat. Grown chiefly in northern Texas. Earlier than Lucretia. Origin—found wild in Texas by John Mayes about 1880.

MCDONALD. Blackberry-dewberry hybrid. Semi-erect growth. Ripens very early, about 10 days ahead of Lucretia. Grown chiefly in the Gulf Region. Self-unfruitful.

MERSEREAU. Erect growth. Susceptible to orange rust. None too dependable in fruiting or propagation. Origin—with J. M. Mersereau, Cayuga, N. Y. about 1890; seedling of Snyder.

NANTICOKE. Originated in Maryland and grown to some extent there as a variety which ripens later than Eldorado.

NECTAR. A trailing type intermediate between Boysen and Young in appearance of berries and yielding less where all three thrive.

PACIFIC. Trailing growth. It is a black-fruited variety of the Young and Boysen type, but of higher flavor. Resembles Logan in shape and size but is less acid. Excellent for the frozen pack and for canning. Well adapted to the Willamette Valley, Ore. Origin—from the same group of seedlings as Cascade. Introduced in 1940.

PREMO. Usually inferior to Lucretia, though esteemed in North Carolina.

SNYDER. Erect growth. Has declined in popularity, except, as in parts of Ontario, where it is somewhat hardier than Eldorado. Comparatively rust resistant but berry appearance is none too good. It cannot withstand dry weather and is capricious as to soil. Origin—chance seedling with Henry Snyder, LaPorte, Indiana, about 1851.

YOUNG (Youngberry). Trailing growth. In southern and Pacific Coast regions its productiveness, large size, deep wine color, sweet flavor, and attractiveness are notable characters. Excellent for freezing for dessert and jam because it holds its flavor well. Adapted to the region from Richmond, Va., to southern Missouri, south to northern Florida, and to the Pacific Coast States west of the Cascade Mountains. Origin—Mayes x Phenomenal, about 1905 with B. M. Young of southern Louisiana; introduced about 1926.

DURATION OF PLANTING, YIELDS AND COSTS

A healthy field of black or purple raspberries produces 6–8 or more crops. The average of many fields, however, is not more than three or four crops, because of virus diseases. The average bearing period of the commercial black raspberry in some districts in Michigan[478] and in Maryland[382] is about six years. With erect-type blackberries and red raspberries 10–12 years of good fruiting is a reasonable duration. Each succeeding profitable crop reduces production costs and emphasizes the importance of healthy plants for setting, isolation from disease sources, suitable soil, adequate drainage, and proper culture.

In California,[248] blackberries usually produce a few berries the second year after planting, reach their maximum production in 3–5 years, and are ready for removal in 7–10 years. In some districts, loganberries die out in five or six years; in others, they last longer. Though the Logan originated in California, a planting does not ordinarily last as long there as it does in Oregon. (See also earlier under districts in California.)

The duration of dewberry, Young, and Boysen field depends, among other factors, on the district, the system of training, and the care. In the South, some plantings 20 years old are still productive.

In general, blackberries and purple raspberries are the most productive, followed in order by black raspberries and by red raspberries.

Yield per acre varies considerably because of such factors as the variety, age of the planting, cultural practices followed, weather, prevalence of diseases and insects, and thoroughness of picking.

In the first fruiting year (the year after planting), black raspberries commonly produce 150–500 quarts, sometimes 500–650 or more quarts, per acre. Pickings of red raspberries and blackberries are usually negligible until after the plants have grown at least a year in a permanent planting. About three years are usually required before a good hedgerow results.

Yields of 3,200 quarts of black raspberries and 2,500 quarts of reds per acre from mature plants are sometimes claimed, but such production on a measured acre basis, in regions where both are grown, is exceptional. Acre averages of fairly good fields are within ranges of 1,700–2,300 quarts for blackberries and purple raspberries, 1,200–1,700 quarts for black raspberries, and 1,000–1,500 quarts for red raspberries. In regions where reds predominate, the yields often average 2,000 or more quarts per acre. Yields

from small plantings, calculated on an acre basis, usually are higher than from fields of an acre or more, which largely accounts for the high yields sometimes claimed. The varieties differ widely in yield; with some reds a yield of 1,000 quarts per acre is exceptional, but with others, as the Latham, it may be doubled on a favorable site. Yields of 1,600 quarts or more per acre for black raspberries are not so frequent as desired. However, growers who use suitable varieties, healthy stock, adequate isolation from disease sources, well-drained soil, and proper methods of culture commonly obtain, even exceed, this quantity.

In Washington,[300] yields of reds vary from 2,000–12,000 pounds per acre. In western Washington yields average 4,500–5,500 pounds per acre.

Table 29

EFFECT OF YIELD ON RED RASPBERRY COSTS. MICHIGAN[531]

Item	*Pounds per Acre*			
	Under 600	*600–999*	*1000–1399*	*1400 or more*
Number of plantings	16	25	18	11
Acres of berries per farm	6.7	8.6	6.7	10.7
Hours labor per acre				
Growing	48	62	73	69
Picking	38	69	115	146
Packing and marketing	4	13	31	25
Total	90	144	219	240
Costs per acre				
Overhead items	$ 34.01	$ 55.51	$.70.33	$ 75.66
Growing	47.26	62.95	68.72	66.35
Harvesting and marketing	27.10	61.56	109.14	127.50
Total	$108.37	$180.02	$248.19	$269.51
Costs per pound				
Overhead items	.07	.07	.06	.05
Growing	.10	.08	.06	.04
Harvesting and marketing	.06	.08	.09	.08
Total	$0.23	$0.23	$0.21	$0.17

In eastern Washington the yields are lower. In Oregon,[49] yields, based on a three-year average, were: reds, 3,370 pounds; blacks, 2,842 pounds; Boysen and Young, 4,764 pounds; and, Logan, 3,425 pounds. In the South, yields of Young, Boysen, Nectar, and dewberries are about 100 crates (24-quart), sometimes 200 crates, per acre. Often yields the second year after planting are not as high as in succeeding years. (See also earlier under California districts.)

From a one-year-old Logan field under good care located in the west, 1-2 tons of fruit per acre ordinarily are secured.[148] At full bearing, the yield will vary with the care in different years and in different districts. Growers, however, should not be satisfied with an average annual yield of

Table 30

COST OF PRODUCTION PER ACRE OF RED RASPBERRIES IN PIERCE COUNTY, WASHINGTON[52]

	Average of 69 Growers	*First 10*	*Seventh 10*	**See note, per cent*
Average yield, pound	6,234	10,386	2,983	
Plowing	$ 7.76	$ 8.68	$ 6.20	1.49
Applying fertilizer	6.87	8.19	5.11	1.32
Training	11.27	13.23	9.89	2.17
Cutting out and burning	17.45	22.69	14.66	3.36
Hoeing	15.03	16.44	13.63	2.90
Cultivating	9.23	12.09	6.74	1.78
Picking	174.70	288.53	92.47	33.70
Hauling	13.51	21.30	8.30	2.60
Supervision	38.77	63.74	26.26	7.48
Fertilizer	25.61	28.23	23.71	4.94
Crates	30.50	53.34	16.56	5.88
Material furnished	4.80	8.42	3.55	0.92
Depreciation	72.28	75.00	70.74	13.94
Interest	77.16	91.80	68.00	14.89
Taxes	12.30	14.25	12.55	2.37
Production costs	91.84	108.55	79.94	18.00
Harvesting costs	258.34	435.35	147.13	50.70
Fixed costs	160.86	181.05	151.29	31.30
Total cost per acre	518.40	734.93	378.37	100.00
Cost per pound	0.0855	0.05789	0.1160	

* Note: Per cent of total average cost. Total acres, 510. Average size farm, 7.4 acres.

Table 31

COSTS OF DEVELOPMENT AND PRODUCTION PER ACRE OF BLACK RASPBERRIES IN OHIO*[415]

	Man Hours (30 cents)	*Horse Hours (15 cents)*	*Cost Dollars*
First-year Costs (Development)			
Labor and power:			
Fitting soil	10.1	17.2	$ 5.61
Planting	13.4	5.0	4.10
Tillage	6.0	7.0	2.85
Hoeing	15.0	0.0	4.50
Applying fertilizer	3.0	2.0	1.20
Removing "handles"	2.0	0.0	0.60
Summer topping	4.0	0.0	1.20
Sowing cover crop	2.0	0.0	0.60
Materials:			
Fertilizer	..	..	5.66
Manure	..	..	11.00
Plants	..	..	38.00
Cover-crop seed	..	..	0.85
Other:			
Taxes, equipment, etc	..	..	12.99
Total	..	..	$ 89.16
Cost of Production in a Good Fruiting Year			
Other than harvest:			
Tillage	11.3	11.3	$ 5.09
Hoeing	15.5	0.0	4.65
Removing old canes	18.8	0.0	5.64
Summer topping	14.2	0.0	4.26
Winter pruning	13.8	0.0	4.14
Replanting	0.8	0.0	0.24
Applying fertilizer	3.3	0.7	1.20
Sowing cover crop	1.2	0.6	0.45
Spraying	3.1	4.6	1.62
Miscellaneous	2.9	0.5	0.95
Harvest:			
Picking: 1500 quarts @ 4¢	..	..	60.00
Trucking	..	..	12.00
Supervision	..	..	15.85
Assembling crates	..	..	7.20
Materials:			
Fertilizer			
Manure			80
Cover-crop seed	..	..	7.80
Crates, boxes	..	..	0.85
Other:	..	..	11.30
Taxes, etc			
Total	..	..	12.99
Cost per quart	..	..	$164.13
	..	..	$ 0.11

* Average of eight growers whose total acreage of raspberries amounted to 40 acres.

Table 32

AVERAGE MAN LABOR REQUIREMENTS FOR RED RASPBERRIES, BLACK RASPBERRIES, LOGAN, BOYSEN, AND YOUNG IN THE WILLAMETTE VALLEY, ORE.

Operation	*Man Hours per Acre*			
	Red Raspberries	*Black Raspberries*	*Logan*	*Boysen and Young*
Removing old canes	38.8	22.1	20.0	29.5
Pruning, brush disposal, and training	..	..	36.4	47.4
Topping	11.9	14.6	..	..
Pruning laterals	..	16.5	..	..
Brush disposal	3.0	5.7	..	..
" " (fall)	..	..	5.8	8.5
Repairing trellis	3.3	.6	2.2	5.4
Staking and laying back	..	..	24.0	15.9
Gathering stakes	..	..	2.4	2.8
Training	8.0	..	..	..
Total for maintenance	65.0	59.5	90.8	107.5
Fertilizing (commercial)	2.0	1.4	1.5	.5
Trucking manure to farm	..	..	1.3	.5
Manuring	1.8	1.8	4.7	3.5
Seeding cover crop	1.0	.8	1.1	.6
Total for fertilizing	4.8	4.0	8.6	6.2
Plowing	1.5	2.2	5.8	3.1
Grape hoeing	4.0	2.3	1.9	3.3
Disking	5.4	6.0	4.1	7.4
Harrowing	..	5.1	4.2	3.3
Cross cultivating	..	4.5	..	..
Other machine cultivating	1.7	2.2	5.5	1.2
Hand hoeing	18.2	23.8	14.6	10.8
Total for cultivating	30.8	46.1	36.1	29.1
Baiting for weevil	2.3	.3	..	.5
Spraying	..	.1	6.8	5.7
Irrigating				.5
Picking	382.6	232.8	279.9	262.2
Supervising, weighing, and checking	42.9	27.8	31.1	29.1
Hauling pickers	6.0	1.3	8.0	8.6
Hauling berries	9.2	10.4	2.1	1.1
Cleaning up camp	.4	..	..	..
Total for harvesting	441.1	272.3	321.1	301.0
Total all operations*	544.0	382.5	463.4	450.5

* Besides the man hours, the overhead labor amounted to approximately 10 per cent on reds, 7 per cent on blacks, 8 per cent on Logan, and 9 per cent on Logan, Boysen and Young.

less than four or five tons per acre and many have been able to secure much larger yields.

PROPAGATION

Tip-layering

Black and purple raspberries, dewberries, trailing blackberries, Logan, Young, Boysen, and a few "reds" such as Dixie, are propagated by tip-layering in the fall. Occasionally, the long canes of black and purple raspberries bend to the ground, become covered with soil largely by rain splashing, and take root. Statements are often made that it is a good plan to assist nature by placing a clod or a stone over the tip portion to encourage rooting. This advice is not practical for propagation on a commercial scale. For good multiplication and good plants, tips should be layered properly by hand at the right time (which is indicated in the subsequent discussion).

Disease Considerations. The condition of raspberry fields with respect to diseases is important when securing plants for setting. Virus diseases, for which spraying is ineffective, may increase rapidly from one year to the next. It has been the experience of many black raspberry growers who set diseased plants to harvest a first or partial crop, one reasonably full crop, and then find that the planting runs down badly. But, if healthy plants are set, serious trouble from virus diseases is minimized. Plants as free as possible from infection are in demand for new plantings. Our standard raspberry varieties are not immune to virus diseases, and the importance of isolation from disease sources must not be overlooked. State nursery certificates are required when a practice is made of selling plants, and "Certified" stock should be emphasized.

A Michigan experiment[24] has shown the importance of starting with clean nursery stock. In 1925, half of a 572-plant Cumberland planting, Section A, was set with tips from plants that seemed free from disease. The other half of the planting, Section B, was set with tips purchased from the trade. They appeared as vigorous as the other lot. During the first summer, nearly 100 plants, or one fifth of those in Section B, showed symptoms of mosaic or wilt and, therefore, were removed. Only one mosaic-infected plant appeared in Section A. The next year 75 diseased plants were rogued out of Section B; whereas only six plants were taken out of Section A. That was the first fruiting year, and Section A yielded 26 cases and B only five cases. In June, 1927, so many of the plants in Section B

showed mosaic and wilt symptoms that it was considered necessary to destroy the entire section because of danger of infecting other nearby plantings. Section A continued to produce well, yielding 36 cases in 1927 and 50.5 cases in 1928. Furthermore, this part of the planting would have done somewhat better if it had not become infected with wilt from Section B.

Soil. The importance of a fairly light, well-drained, fertile soil for propagation cannot be overemphasized. An Ohio experiment with over 50,000 plants showed a loss of more than 50 per cent of rooted tips on heavy, rather wet soil in contrast to a 5 per cent loss on sandy or gravelly loam. The losses were especially severe with tips that did not become well established because of late layering and because of heaving. On heavy soils it is often impossible to dig plants in the spring until growth is so far advanced that much injury results to the plants; also, digging is slow and expensive.

Age of Field. The black raspberry is not grown in nursery rows simply to secure new plants by tip-layering. The common practice of the larger nurseries is to purchase plants, often under contract, from growers who fruit their plantings as well as propagate new plants. One-year-old fields are sometimes preferred to older fields as a source of tip-layered plants. There is some justification for this, as the 1-year fields frequently show less disease. Thorough inspections and good cultural care tend to equalize possible differences and make tips from mature plants as suitable as those from 1-year plants.

Number of New Plants. With good care an average of 10 new black raspberry plants can be obtained from each vigorous parent plant after a year's growth, especially if more than one plant is rooted from each branch. An average in good fields is 5–6 rooted tips per parent plant. About 10,000 plants per acre is a reasonable production for a 1-year field, after allowing for missing plants and other factors. In later years a greater number may be dug. Probably 15,000 plants per acre is a fair estimate for mature fields, though more may be obtained if the plants are kept low and the stand is good.

With the purple raspberry a lower percentage of layered tips take root than with the black. The purple matures its crop later and the tip-layering is later than with the black. Frequently this results in more heaving out of the purple tips. However, the purple, because of greater vigor may produce as many, and in some cases more, plants than the black raspberry.

Black raspberry propagation. Unbranched laterals usually produce the best plants; however, if the secondary laterals are long, good plants may be produced from them. The root systems of the nine new plants here are small but good and will be somewhat larger at digging time. Very short secondary laterals may result in one seemingly large plant which really consists of a number of small plants and this is undesirable.

BRANCHING OF LATERALS.* Each lateral from a first-year cane may produce more than one tip plant, as the laterals tend to branch just before rooting. Thus more plants are obtained, but they are usually smaller and lack the well-developed root systems of unbranched tips. As many as 10 secondary lateral plants develop in some cases; 60 of them have been seen in an exceptional case. Secondary laterals which are about eight inches long generally form good root systems. Frequently, however, the second-

* The cane of *Rubus* is biennial. Bailey[20] proposed the following terms to clarify the confusion in the literature: *primocane*, to designate the first year's growth; *floricane*, to designate the second year. However, from the standpoint of cultural practices, it seems preferable to classify canes as "first-year" canes and "second-year" canes in the text. The expression "first-year" cane is applied to the growth which is made from below the soil surface during the current year and, as well, the period continuing through the winter or dormant period; it also includes canes which fruit at the tip in the fall. The expression "second-year" canes is applied to first-year canes in the succeeding year when they make fruiting shoots, bloom, bear fruit, and die; it includes the period after the canes have fruited until they are removed from the planting. A "lateral," as used here, refers to a branch from a first-year cane; a "secondary lateral" is a short branch near the tip from a lateral. A lateral growing from a second-year cane is a "fruiting shoot."

aries are short when tipped, and the increase in number of new plants is offset by poor, or only fair, root development. The development of secondary laterals is due chiefly to the bruising of the tips of primary laterals through being whipped by wind. To determine whether or not a late-summer cover crop would, by forming a mat, reduce injury to the tips through being whipped over the soil, soybeans, oats, golden millet, and buckwheat were used in successive years in Ohio, but less than 50 plants rooted of their own accord in the 850-plant field. Bruising of the tips was not prevented.

Black raspberry lateral cane ready for tip layering. The tip portion has lengthened out in "snaky" or "rat-tail" fashion, with scanty leaf development. The lateral is unbranched, which is the preferred condition.

SUMMER TOPPING. Tip portions of laterals of unchecked first-year canes often are so spindly that sturdy plants are not obtained. As plantings become older, the bushes often become higher and many laterals fail to reach the ground. Proper summer topping (see later) avoids this condition.

TIME FOR TIP-LAYERING. The development of a good root system depends much on the time of placing the tips in the soil. The best time for layering the black raspberry is when the tip portions of laterals of the first-year canes lengthen in "snaky" or "rat-tail" fashion, with small, curled leaves. It is advisable to begin layering when some laterals have reached this condition, and most of them are nearing it. Tips put down too early usually push out of the ground. They can again be layered, but the part of the shoot initially underground makes a poor plant at the first point of contact. Relatively early tipping is preferable to late. Late tipping may result in several small plants from secondary laterals instead of a single well-rooted plant from each lateral

Black raspberry cane tip layered too early. It rooted, grew out of the soil, and rooted again. The tip plant (*right*) is the best of the two for planting but neither of them is a first class plant.

and in much loss from heaving out. The tip-layering period usually begins in late August or early September, and depends on the region, the moisture supply, and the year, and lasts for about a month. Since all tips are unlikely to be ready at one time, it is a good plan to go over the field several times.

METHOD OF LAYERING. Better plants are obtained by using a narrow tiling spade or heavy trowel than by plowing a furrow. Plowing facilitates rapid work but leaves much to be desired in the grade of tip plants. On light, loose, dry soils, where the soil falls back into the hole easily and makes the placing of the tips into it difficult, a comparatively wide tool is preferable to a narrow one. On heavy, compact, rather moist soils, a narrow implement, which lightens the labor of making the hole, is better.

Three or four inches of soil make a good covering, the depth varying with the type and condition of the soil. Shallow tipping may result in much loss from whipping out, heaving out, and other causes, as well as from poor root development. Very deep placing of the tips in the soil, especially in clay soils, may result in breakage of many of the tender growing points in digging. A vertical rather than a horizontal method of tip-layering the plants is best. Inexperienced growers usually employ the "horizontal" method, thereby not obtaining the best plants.

Rate of Placing Tips in the Soil. The number of tips of black raspberries layered in a 12-acre field in a 10-hour day, with a narrow spade on a clay loam soil in Ohio, averaged between 2,000 and 3,000 per man. Under good conditions, one man, exerting himself for an hour, placed 900 tips in the soil. In general, the range is between 1,000 and 4,000 tips per day, depending on the man, the soil type, and soil conditions.

Removal of Second-year Canes. It is better to remove the canes after fruiting than in late winter, as it permits more thorough inspection for diseases, avoids tramping on the tip plants when removing the brush, and facilitates layering.

Digging. The tips, under favorable conditions, become well rooted by the end of the growing season. Leaving them attached to the parent plant over winter is better than severing them in the fall, unless fall planting is practiced.

On light soils the use of a four-prong potato *hook* finds favor for digging; on heavy soils a four or five prong potato *fork* is a good tool. Tying plants in bunches of 25, one tie being near the crown, is better than throwing the plants into bushel baskets or other containers. An objection to the latter method is the breakage and difficulty encountered in separating the individual plants.

In separating the layer plants from the parent lateral canes, leave 6–8 inches of cane on the tip plants as it is more satisfactory than pruning longer or shorter. The "handles" may be shortened later to about 4–6 inches, so that the end of the tied bunch is uniform. If the canes attached to the new plants are left full length after the dormant pruning in order that the "brush" can be removed from the field in bundles with each 25 tip plants, the procedure is slower than removing the brush in a separate operation.

Late digging interferes with work involved in culture for fruit, increases anthracnose infection, and is one of the few ways in which propagation of new plants may reduce the fruit crop.

Black Raspberry Plant Propagation Costs

In a Michigan study[477] of four raspberry fields, the plant production costs ranged from $3.25 to $4.57, and selling prices from $5.50 to $10.00 per thousand.

An estimate of the number of plants which a man may tip-layer in a day was given previously. To dig, bundle, and pack 1,000 plants is a good average for a day's work. Some expense should also be charged against growing the plants even though fruit production should receive the major charge. If the demand for plants is not good, the cost of producing both those which are sold and unsold should be taken into account. When plants are dug late in the spring a reduction in yield of fruit may occur which might provide an appreciable item of expense against propagation. Advertising is often a large part of the cost involved in the propagation of plants.

Propagation by Suckers

Red raspberries are propagated by suckers that grow from the underground stems. These suckers appear in the spring and continue to do so into the summer and are the forerunners of nursery plants.

Red-raspberry plants may be obtained either by digging entire nursery rows or by digging near mature plants. It is probably better to set aside a portion of the field for propagation and dig all the plants than to dig freely throughout the field. Red-raspberry plants with well developed, so-called T-roots are desirable. Usually the plants are dug by hand, but large nurseries sometimes use special digging machines when the rows are dug clean. It is important that the young plants actually be dug, not pulled; otherwise, only a straight stub with few roots poorly equipped for growth may be left.

Types propagated by tip-layering, such as black raspberries, produce a number of plants after one growing season; whereas with types propagated by suckers, such as red raspberries, an additional two years are required before there are many plants for sale. After the field is established for propagation purposes many more plants are expected per acre from reds than from tip-layered types; ten times as many new plants per acre from reds as from blacks is not uncommon. There is less work involved in the propagation of red than of black raspberries in that layering in the fall is unnecessary.

The following records* of the Chief variety indicate the rate of stock increase in a red-raspberry nursery planting.

* Unpublished records; courtesy W. G. Brierley, University of Minnesota.

Year	*Plants Set*	*Dug in Fall*	*Sold*
1927	14	157	0
1928	157	1,765	75
1929	1,690	13,230	5,980
1930	7,250	..	Dug and sold in quantity

Though spring suckers sometimes thrive well when set in early summer of the year in which they appear, they are not ordinarily used for permanent setting, chiefly because of their small size and perishability.

Blackberries, like red raspberries, can be propagated by suckers, but nurserymen mostly use root cuttings. As a rule, largely because of the more rapid rate of reproduction, growers prefer blackberries from root cuttings, and claim (whether or not properly) that the plants generally develop a better root system than do those from suckers. There is no justification for the claim that blackberry varieties come truer to name from suckers than from root cuttings, or vice versa, unless carelessness is a factor.

Propagation by Root Cuttings

Good blackberry cuttings are 3–4 inches long and as thick as a lead pencil. Though success follows the making of cuttings in spring and setting them promptly in nursery rows, yet the work is usually done in the fall. Cuttings made in the fall are stratified in moist sand or other suitable material or they may be buried outdoors over winter in a well-drained site. When set in the nursery row, they are placed horizontally in a trench and covered with several inches of soil. If the cuttings are small and spindly, it may be best to place them end to end, or even in double rows; but, if they are of good length and thickness, spacing 3–6 inches apart in a furrow is suitable. Greater growth the first year can be secured by setting the cuttings in a frame with slight bottom heat supplied by manure. A surprising number of cuttings can be made from a blackberry plant with a strong root system. After a year in the nursery the young plants should have developed sufficiently to be dug and set in a permanent planting.

Handling Plants for Shipment

Source of Plants. Obtaining small-fruit plants from good fields of the desired varieties near where they are to be grown reduces the time be-

tween digging and planting and keeps down shipping charges. Every day that the plants are out of the ground may lower their vitality greatly. Many growers wisely insist on going to the nursery planting to select the plants which they buy and take away and then setting directly in their fields, the same day if possible. The majority of plants raised, however, are shipped. Requirements of various states must be met in shipping from one state to another. In some cases, all that is necessary is to file the certificate and the name of the nursery; in others, a certificate must be obtained from both. In shipping to foreign countries, Customs regulations must be complied with.

When to Dig and Ship. The plants should be dug and shipped as near the dormant condition as soil and weather permit. Prospective growers should order plants at an early date. After the plants are dug they should be covered and taken without delay to the packing shed or storage room, or they should be heeled-in, if shipment is not to be made at once.

The season when the plants should be dug varies with the region. Many large nurseries in northern areas dig red-raspberry plants in the fall and hold them in storage over winter. This is necessary to permit early shipments to earlier regions. Fall digging of reds in the East is often practiced, though spring digging is usual. Black raspberries, which are propagated by tip-layering, are usually dug in early spring.

Packing. When plants are handled in large quantity, it is often necessary to hold them some time after they are dug until they are sold. Drying out, heating, and growth are probably the three chief factors to guard against. Heeling-in is a fairly efficient method of keeping nursery plants for a limited time.

In packing, the plants are surrounded with sphagnum moss, straw, excelsior, or other material that has been well soaked and squeezed free of surplus water. The proper amount of water to leave in the packing depends on such factors as the distance the plants are to be shipped, type of container, number of plants in the container, temperature, and stage of growth. Too much moisture in the moss may result in heating (due largely to respiration), but most complaints seem to be that the moss was too dry rather than too wet in small packages. Only plants with good thrifty root systems should be packed and shipped. All plants affected with crown gall should be discarded. If there is crown gall in the field, washing the roots before shipping may spread the disease among the plants.

Small-fruit plants are successfully shipped in many kinds of packages. Small orders (two dozen plants) filled when the plants are dormant or nearly so can be wrapped in special commercial paper; oiled and heavy wrapping paper are sometimes used. Orders of 100 black-raspberry plants may be shipped satisfactorily in packages, such as the 16-quart split grocery basket, wrapped in heavy elastic wrapping paper. Bushel baskets or strong boxes of similar capacity are reasonably suitable for 200–300 tip plants depending on the size of the plants. Not more than 250 tip plants with large root systems should be placed in a bushel-size package. Orders for 750 plants and up are economically packed in used barrels. Larger boxes are suitable in late fall or very early spring when plants are dormant; otherwise, there is danger of heating in long shipment. If a hardware or other thin-wood box is used, it should be braced and wired against rough handling. A certain amount of ventilation in the package is necessary, particularly with late dug plants.

In filling bushel baskets or other packages with tip plants, place a layer of damp (not wet) packing on the bottom, then a layer or two of bunches of plants with roots to the sides and tops to the center, then packing, and so on. Packing should also be placed between the plants and the inside of the package After a few layers of packing and plants have been placed in the package, the contents can be pressed firmly. In barrels, about six inches of dry straw is placed over the packing of the upper plants. The highest hoop is taken off, burlap placed over the end, and the hoop replaced and nailed. The plants should be packed firmly. If any growth has started, the green shoots should not be in contact with moist packing.

LOCATION AND SITE

Soil

Remarks on soil given previously for grapes and strawberries apply, for the most part, to the bramble fruits. The returns from a high yielding planting are such that the grower can afford to use his best land for these crops.

The ideal soil is a fine deep sandy loam, well supplied with humus and retentive of moisture, but well drained. Fruiting comes at a time when soil moisture is low, and so a soil that is retentive of moisture is to be preferred. Some red-raspberry varieties, for example, thrive best on certain

soil types, that is, June on a clay soil, Cuthbert on a light soil, and Latham is more cosmopolitan in its requirements. Where crown gall is a factor the heavier type may be preferable. Soil reaction, other than extremes, is not greatly significant, but a slightly acid soil is usually said to be best. For propagation by tip layers, as explained earlier, a light soil provides certain decided advantages.

The importance of favorable subsoil conditions for the growth of brambles is not generally recognized. A compact, impervious subsoil, retarding the downward movement of water, is detrimental to root development. The character of the subsoil should be determined before the site is chosen, either by boring into it with a soil auger or by digging holes at frequent intervals over the field. The subsoil should be loose enough to allow good underdrainage and permit good root growth, but should contain enough clay to prevent too great a loss of water. Extremely sandy and gravelly subsoils usually allow too much drainage.

The Young, Boysen, and Nectar display most of the properties of dewberries[184] in that they thrive on shallow but well-drained soils. They can be grown on many types of soils, including the sandy, cherty, and stony soils. On the heavier, richer soils they may grow too vegetatively, and consequently produce few berries. These types develop a deep root, are able to get moisture from a considerable depth, and are not as subject to drought as are raspberries and blackberries. The Boysen probably needs a richer soil than does the Young.

Water Drainage

The plants with roots that penetrate comparatively deep and are not partly killed by poor water drainage or a high water level are best able to absorb moisture from lower depths in dry periods. Adverse effects from reduction of the root system are shown in the summer when rain may be scarce during the period when the plants are growing and maturing their fruit. Reduction in the root system reduces growth and causes greater susceptibility to winter injury.

Where the water level remains low throughout the year or where it approaches the surface for only a few days in the spring, the roots penetrate deeply and branch profusely, shoot growth is vigorous, and yields moderate to heavy. Where it is high throughout the year or for a comparatively long period in the spring, the root system is shallow, cane and shoot growth is poor, yields are low, and the plants are short lived.

In loam soil in the Puyallup Valley, Wash.,[297] reds will not thrive if the winter watertable is closer than 2½ feet to the surface; three feet is better. Bush blackberries are not so easily damaged as raspberries but should not be expected to produce high yields if free soil water remains long within two feet of the surface. Evergreen blackberries endure more winter soil water than most other berries. Many Evergreen plantings are located on land where the winter watertable is within 12 inches of the surface for weeks at a time.

In the year of their setting, young raspberry plants may make good growth in a poorly drained site, but adverse effects will appear in the second year. An excessive fall water supply may delay maturity of the cane wood and the canes next spring will show various degrees of weakness or death from the winter temperatures. Also, the natural rise of the watertable near the soil surface during winter and spring may suffocate large portions of the root system underground and weaken the crowns. Spur growth on the fruiting canes cannot be supported by the depleted root and crown system and will turn yellow, wilt, and die preceding harvest. The new canes may also exhibit wilt symptoms, with drooping and yellowish leaves, and even purple striping. Frequently, however, especially toward fall after a new root system has developed in the dry period, growth of new canes may be normal. But, such growth is ineffective, as drowning of the root system will occur again in the winter and early spring and the canes will collapse while fruiting. Too heavy soils, or those with "hardpans," should not be planted to raspberries, regardless of how fertile they may be. Sites where water collects and stands in depressions or pockets, or where springs keep the soil saturated, should be avoided. No site should be used for raspberries where water will stand for a whole day. Tiling will help correct poor drainage conditions but is at best only a substitute for naturally good soil-water relations.

Because of their deep root systems, the Young, Boysen, Nectar, and dewberries are not adapted to wet soils with their accompanying root rots. Soils with silica hardpans 12–14 inches below the surface must be avoided.[184]

Exposure

Slope. Steep slopes are likely to wash badly and cannot be worked so well as land that is nearly level. However, profitable raspberry fields do occur on steep hillsides, in some areas. The ripening of a variety may be

influenced by planting early varieties on a southern slope and late varieties on a northern slope. Southern slopes sometimes are conducive to winter-killing of canes, through warming up the buds and inducing breakage of dormancy prematurely in spring.

WIND. Protection from wind provides some advantages, such as steady bushes in picking and since snow drifts less and remains longer there is less evaporation from the soil and canes and consequently less winter injury. However, where air drainage is poor, mildew, spur blight, and anthracnose may become more serious. Where irrigation of raspberries is essential, as in Colorado, the slope should not be so steep as to make irrigation difficult or soil erosion a problem.

Cane breakage caused by wind[135] is a common condition in many areas. It is most frequent on the new shoots of black and purple raspberries and also with the fruiting canes of red raspberries. The cause of such injury would seem to be most obvious but oftentimes is not.

The weakest point in the raspberry plant structurally is the attachment of the canes to the crown. Whipping of the canes by wind or striking them with the cultivator often partially disrupts this union. The breakage is underground and goes unnoticed. Injured canes may wilt completely and die in a few days or they may live for several days or even weeks, displaying various baffling symptoms. In the case of injury to new shoots, the tips may die back, a broad blue stripe may creep up the stem from the base, the leaves may gradually turn yellow and drop, and weak, new growth from the secondary buds on the cane may give the plant a peculiar bunchy appearance. Such symptoms are easily mistaken for mosaic, wilt, winter injury, or injury by root-feeding insects. Injured fruiting canes gradually wilt and the berries dry up.

To detect the cause of the trouble, take hold of the injured cane near the up and move it back and forth. The looseness of the cane at the crown will be evident, and a gentle pull will usually break it away entirely. Upon examination, the basal end will show bark callus and brown, dry wood and pith over the major portion of its surface where the partial break occurred some days previously. The callus formation never succeeds in repairing the injury, and the unbroken part of the cane is not sufficient to maintain the cane in a normal condition.

To avoid such mechanical injury, sites for raspberries should be chosen which have some measure of protection from strong winds. In black and

purple raspberries, low summer pinching of the new tips eliminates the high-bush, top-heavy sort of canes that are most subject to wind-whipping. A low ridge of soil maintained over the crown gives some support. Posts or trellises to support the canes may be necessary in some sections. If the old canes that have fruited are left in place through the ensuing fall and winter, they will support the new shoots to some extent. Striking the canes with cultivating implements is inexcusable.

Previous Crops

It is a good plan to plow under a green manure crop before planting cane fruits. Land on which corn or other frequently cultivated crops grew a year or more previous to planting is usually suitable for cane fruits. Old grass sod plowed and immediately planted to cane fruits is not satisfactory; such soil usually lacks proper texture and fertility, is rough and difficult to plant and work properly, and is hard to keep free from grass. If land in sod is selected as the site, it should be plowed in early fall and be thoroughly worked before planting in the spring. Fields infested with quack grass and the like are difficult to keep clean.

Verticillium wilt sometimes is serious when black raspberries, particularly stock of weakened vitality, follow tomatoes, potatoes, eggplants, or muskmelons which are infected with the disease.

Isolation from Disease Sources*

In brief, as a general recommendation, healthy black raspberries should not be set within 20 rods of red or purple raspberries, wild brambles, or diseased cultivated plants. Mosaics and leaf curls are spread by plant lice which, after sucking the juice from diseased plants, such as red raspberries, feed on the blackcaps. Most reds carry a high percentage of a masked form of green mosaic which is not greatly harmful to them, but after the aphids have transferred the disease to the blacks it becomes serious. Soil on which crown-gall disease existed on plants should not be used for a number of years thereafter for cane fruits. Sometimes plantings are found which have thrived beyond the average length of life and which are heavily infected with crown gall. Nevertheless, crown gall undoubtedly tends to shorten the life of raspberry plantings and reduces yield.

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* See also discussion on Diseases.

Red raspberries *(extreme left and right)* and black raspberries *(center)*. The reds are thriving well; whereas the blacks mostly have died. Poor drainage, as in the foreground, is partly responsible; but inspection of the blacks showed a very high percentage of disease which had spread from the reds. Universally, black raspberries are short lived when planted near reds. The two types should be separated by at least 20 rods.

Bramble Fruits in Orchards

Raspberries or blackberries sometimes can be used to advantage in a young orchard and made to furnish a source of income while the orchard is being established. The disadvantages of interplanting, however, may exceed the advantages.

Raspberries or blackberries should not be set within 10–15 feet of newly set trees. As the trees grow older, the berry plants should be kept three feet or more from the spread of the branches. Cane fruits should be set only between every other tree row so as to allow for passage of spray machines. When apple trees are spaced 40 feet apart, as many as three rows eight feet apart of raspberries or blackberries can be set between them. With peaches or other trees only 20–24 feet apart, more than one row of brambles should not be set between the tree rows. For the most part, black or purple raspberries reach the end of their life by the time apple trees reach profitable bearing, but they may still be productive when peaches begin to give good yields. Red raspberries and blackberries, which are longer lived than blackcaps or purples, overlap more in production with tree fruits. Cane fruits may be damaged by spray material used on fruit trees relatively late in the season.

Cane fruits may be set between the trees in the row. This does not give

so much acreage of cane fruits as can be obtained from setting between the tree rows, but the results sometimes may be worthwhile.

The bramble fruits draw heavily on the soil for moisture and nutrients and return little in plant residue. Increased attention to humus content and fertilizer is necessary when they are grown in an orchard.

Bramble fruits are taller growing than such crops as strawberries or vegetables, and the habits of growth and spiny condition of the canes make them somewhat difficult to handle in an orchard. Raspberries and blackberries, well spaced, can be cultivated in one direction throughout their lifetime, but when planted as a companion crop in an orchard cross-cultivation of the orchard is seldom practical.

Effects of Conditions on Adaptation

Two good examples of the effect of conditions on adaptation are:[160] (a) the Viking red raspberry, which is hardy in parts of Canada but not in Maryland, and the Latham, which is hardy both in Minnesota and in Maryland; (b) the Van Fleet raspberry which commonly makes a cane growth of 8–10 feet but in the hot interior valleys of California may grow to 25–30 feet.

In southern areas the red raspberry is virtually an unknown fruit. The failure of the American species to grow in this region is not only because of its susceptibility to disease but also its lack of adaptation to the long summer season and the high soil temperatures. Certain Asiatic species are well adapted to the South and crosses have been made with the red raspberry. (See Dixie, under Red Raspberry Varieties.)

Drought Resistance. Certain black raspberries, e.g., New Logan, are more drought resistant than others; e.g., Cumberland. The dewberry is outstandingly drought resistant.

The erect blackberry, with its shallow root system, ripens in midsummer, later than the strawberry and raspberry and when evaporation of soil moisture is the most rapid. Droughts are, therefore, a serious menace. In sections where there are frequent drying winds during the ripening period or during the winter it is important to choose a sheltered location. Though wild blackberries are abundant in the northernmost part of the United States and in the milder areas in Canada, they are found chiefly in woods and thickets where there is protection from cold, drying winds in winter.

Winter injury in red raspberry. Note that the canes are leafing only at the base. The upper parts are dead. (Courtesy, Hort. Exp. Sta., Vineland, Ontario.)

Furthermore, cultivated varieties are selections from wild species of blackberries which are found mostly in the more temperate parts of the country, rather than from one species native to the colder and more exposed locations in the north. For these reasons[163] cultivated varieties are chiefly adapted to the more temperate sections of the country.

When there is a deficiency in soil moisture the foliage of the red raspberry can absorb water and the water so absorbed moves readily within the plant.[63] Water appears to move readily either upward or downward within the canes. The conducting capacity of the individual cane is much in excess of the minimum requirements of the cane, and the ease of water movement is independent of variations in the number, diameter, and length of the tracheae.

Hardiness and Winter Injury.* Hardiness is generally considered as related solely to resistance to low temperature, but a number of other factors should rightfully also be included. In general, the red raspberry is hardy farther north than are the other brambles; the purple raspberry ranks next in northern adaptation; the black raspberry is more hardy in the north and more tender in the south than the dewberry or trailing blackberries.

* See also Winter Protection.

SEVERE COLD. Suitability of varieties to a given district often depends, as in northern regions, on tolerance of severe cold. There are inherent differences between varieties in this respect. In Alberta, Canada, for example, the Chief red raspberry is very much hardier than the Taylor. Chief, with only windbreak protection, produced a good crop following a winter in which the temperature dropped to −50° F. at Edmonton, whereas Taylor killed to the snow line. The Chief is able to endure severe cold if well matured and hardened, if the canes stay that way and are not subjected to one or more of the adverse factors as set forth in the subsequent discussion.

REST PERIOD. In the fall, raspberry canes become "dormant" (without leaves). The buds also enter a "rest period" and while in the deep rest will not "grow" even when the surrounding temperature reaches 50° F. (or even at about 43°, the point at which growth in woody plants usually begins). Just when the rest period breaks is uncertain, and may vary with the region and year. Probably the "rest" in raspberries is ended by the first spell of zero weather in the fall. In Minnesota,[78] it takes about 65 days for buds to start in October and only 7–8 days in December if conditions occur that will break the rest. The rest period is earlier and lighter in long growing seasons, later and deeper in short growing seasons.

Buds in the basal portion usually break after those at the tip, and those in the central portion start last, but time of bud activity does not seem to be related to growth vigor. As the tip portion of the cane represents growth occurring in August and early September in Minnesota, it actually is the product of a very short season. That rest is broken earlier in the tip region supports the belief that intensity and duration of rest in the cane as a whole are related to length of growing season, developing later in short seasons.

Injury may be due to alternating spells of cold and warm weather late in November or in early December. Well matured canes go into their winter rest. A cold spell at 0 to 10 degrees above is likely to break the rest so that the buds become active when the temperature rises above 15° F. On such days bud temperatures may be 10° or more above air temperatures. If the warm weather lasts for several days the buds may begin the early stages of development and no longer are dormant or hardy. Sometimes they swell and show green tips in December. These developing buds are killed when the weather turns cold again. This injury is not likely to occur

in winters when there are no unseasonable warm spells. When the buds are killed the cane is unable to form new ones and dries up in the spring. The spring appearance of this sort of injury is that the bud scales are separated and the bud, though dead and dry, is larger than a normal, tightly folded dormant bud. Sometimes under these conditions the cane itself may be injured and some of the buds survive. These buds develop but the canes dry up during hot weather in summer because they cannot carry enough water.

Injury to matured and hardened Latham canes following exposure to controlled warm temperatures. (A) Not exposed to warm temperatures. (B) Two days at 45° F.: 24 hours at −8° F. (C) Four days at 45° F.: 24 hours at −8° F. (D) Eight days at 45° F.: 24 hours at −8° F. Injury in the field similar to that of Nos. 2, 3, and 4 generally has been attributed to immaturity. (Courtesy, Dr. W. G. Brierley, University of Minnesota.)

A raspberry cane needs to be hardened to withstand low temperatures and the rest does not make it hardy. Rest begins during relatively warm fall days, and the deep rest may be reached before hardening has begun.[64] Hardiness, or resistance to cold, is developed by exposure to freezing. It proceeds gradually when hard frosts occur frequently. Exposure for several nights to around 20° F. or lower is necessary to fully harden the cane, but the rest is not broken until after the cane is exposed to much lower temperatures.

SUDDEN COLD. Injury to canes may occur when the temperature falls suddenly below zero. But, Latham and Chief raspberries can endure severe cold if well hardened. Light frosts and one night at 20° F. do not harden well matured Latham canes enough to prevent killing by sudden exposure to zero.[65] This treatment kills cane tissues but the buds are uninjured. After exposure for four nights to 20° F. and then to zero there is slight injury to cane tissues and no injury to buds. Such injury might be related

to subsequent drying of the canes during the picking season. Injury of this sort is due to early, sudden cold before the canes were fully hardened and is not at all related to immaturity. Sudden cold occurring relatively early, perhaps in mid-November may cause much injury. The effects of sudden cold during winter months depend largely upon the occurrence and duration of mild spells immediately before the cold weather.

WINTER DESICCATION OF CANES. The rest period may also be broken by desiccation of the canes. Possibly, therefore, drying winds may bring about this condition and, when followed by warmer temperatures during the winter, the buds may begin to "grow."

In regions where the winters are severe, and particularly where the atmosphere is relatively dry, canes which are not protected from winter winds may dry out beyond recovery. Dr. Brierley has made this comment:[124] "This can happen even when the ground is not frozen as the intake of the roots is so slow in cold soil that replacement of water losses from the roots can be inadequate to hold the moisture above 50 per cent of the fall (mature) content. Again, when the soil freezes deeply and drying winds are frequent in winter or early spring before the soil thaws, the roots are not able to replace the water that evaporates from the buds and canes. Sometimes the canes cannot recover even when conditions are favorable later on in the spring. Probably more of this type of injury occurs in the western part of Minnesota where rainfall is less and drying winds are more common. Because of the danger from drying it is not a good plan to mulch the field when the ground is frozen. Mulching at this time may lead to this injury as the soil beneath a mulch may remain frozen late enough in the spring for drying to occur before the roots become active."

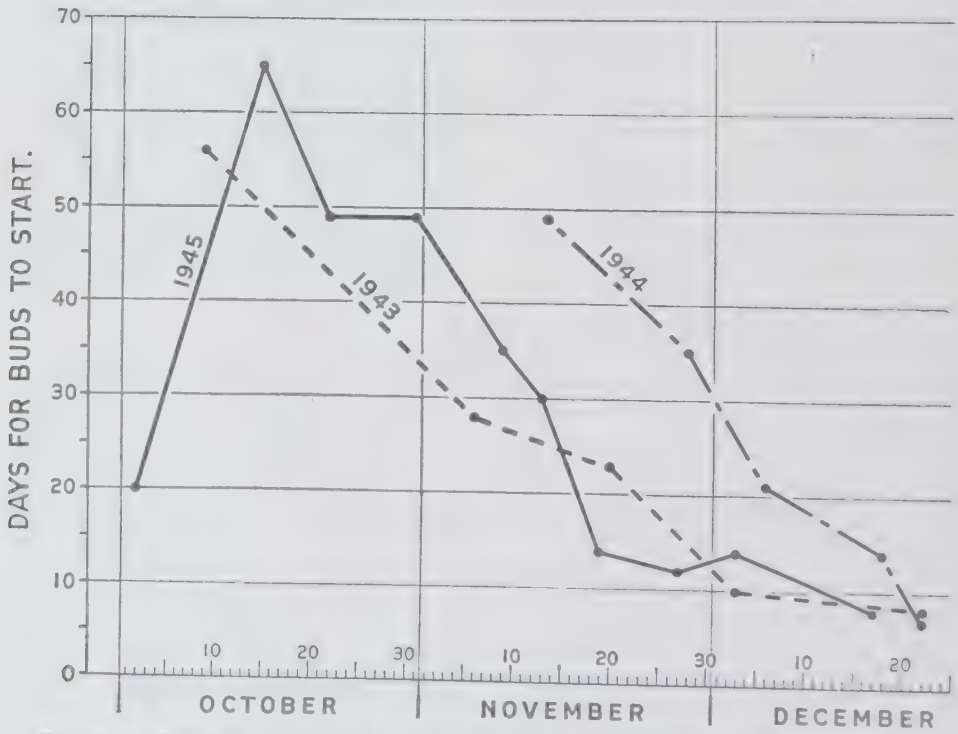
Frequently canes will not only dry in winter or early spring following injury from fluctuating temperatures, but, as well, after injury from such causes as borers, tree crickets, or severe crown gall infection.

IMMATURITY OF FIRST-YEAR CANES. Vigorous, robust canes are desirable in bramble fruits providing the main growth is made early in the year. If, however, the first-year canes continue to grow late in the year they may be succulent and tender when a fall freeze occurs. Though the damage from cold is usually most pronounced toward the upper part of the canes, even the basal part may be injured under very unfavorable conditions.

Immaturity is not as important a cause of injury as has been supposed.[61] Such injury may follow late cultivation, or it may occur when raspberries

are grown on heavy soil or on peat. Injury is common at the tips of the canes but usually extends only a few inches down from the tips and so is of little importance as the tips are removed in spring pruning. Cane growth usually is finished by mid-September, thus allowing 6–8 weeks for development of maturity and for hardening before severe cold weather arrives. In some years fully matured canes have been injured, but in other years there has been no injury. It seems likely, therefore, that injury has been caused by some factor other than immaturity.

Though the time when growth ceases is not a measure of the degree of maturity finally reached by cane tissues it is a measure of length of time during which maturity may proceed.[65] At Duluth, in two years when growth ended by mid-September no injury occurred. In a year when growth ended on September 23, 50 per cent injury was noted the next spring. But, in a year when growth ended by September 7, the earliest date recorded in five years, 75 per cent injury was noted the next spring. In states farther south where cool wet weather may follow high summer



Duration of rest period in the Latham raspberry in Minnesota. Curves show number of days in greenhouse for buds to start on canes collected on the dates shown. (Courtesy, Dr. W. G. Brierley, University of Minnesota.)

temperatures canes may make late or second growth which is likely to be injured during the winter.

Cane maturity may be influenced by attacks of insects or diseases. For example, Anderson and Kadow (Ill. Hort. Soc., Vol. 76) state that anthracnose and septoria leaf spot are serious diseases of Latham in Illinois and that the grower should follow a definite spray schedule using Bordeaux mixture, especially in southern Illinois where the leaves must be retained as long as possible in order to prevent a secondary growth late in the year. They also recommend the use of summer oil sprays against red spider.

Several procedures are helpful in preventing damage associated with immaturity of canes, such as, ceasing cultivation relatively early, use of cover crops, and following sound practices as outlined in the text.

VARYING TEMPERATURES. Much injury to canes may occur when temperatures vary from cold to warm and to cold again at almost any time from November to April. The factors involved in this behavior are:[64] (a)

Table 33

RELATION OF VARYING TEMPERATURES IN THE DORMANT SEASON TO EXTENT OF CANE INJURY AND REDUCTION IN CROP VOLUME THE NEXT YEAR[65]

Year	*Temperature Conditions in Dormant Season*	*Extent of Cane Injury*	*Effect on Crop Following Year*
1937–38	Varying cold and warm.	General but not severe. Some canes dried in summer.	1938 crop reduced. Sudden drop in midseason.
1938–39	No warm spells.	None evident.	1939—Good crop; no drop in volume.
1939–40	Varying cold and warm.	Widespread and severe.	1940 crop reduced 50 per cent or more.
1940–41	No warm spells.	None evident.	1941—Heavy crop; no drop in volume.
1941–42	Varying cold and warm.	Widespread and severe. Some canes dried in summer.	1942 crop reduced more than 75 per cent.*
1942–43	Variable in November and March.	Average injury 40 per cent.	1943 crop reduced more than 40 per cent.
1943–44	Varying cold and warm.	Widespread and severe.	1944 crop reduced more than 50 per cent.

* Loss in volume due in part to injury from poor subsoil drainage.

Cold weather breaks the rest. (b) A few days with air temperature above freezing may bring about the loss of hardiness or resistance to cold. (c) If the temperature rises above 45° F. for a few days, with little or no frost at night, buds may begin the very early stages of growth initiation and thus be neither dormant nor hardy. (d) Subsequent cold, particularly sudden cold, is likely to cause severe injury to canes that have lost their resistance to cold or to those that may actually have begun the early stages of bud activity.

At Duluth, Minn., when the weather stayed relatively uniform with no warm spells as in 1938–39 and 1940–41 there was no evident cane injury and good crops were harvested the next year, Table 33. In each of the other five years warm spells in the dormant season were followed by injury to canes and reduction in yield. Though some of the injury in 1941–42 was due to poor subsoil drainage, injury in every case followed varying temperatures and did not occur in years when temperatures were more uniform. Thus there is a close relationship between warm spells in the dormant season and injury to canes.

The varying percentages of injury recorded at Duluth probably reflect the varying durations of warm spells in the dormant season, temperatures that occurred during such spells, and the rate and extent of temperature fall after the warm spells.

RESISTANCE OF ROOTS TO COLD. In the Latham no injury was found at soil temperatures above −2° F., and the killing point was between −6° and −9° F.[72] Therefore, under usual winter conditions in Minnesota severe injury or killing of roots of the Latham are not likely to occur.

ENVIRONMENT. There is a relation between such factors as soil moisture supply, temperature, humidity, and sunshine and plant performance. A liberal and constant supply of soil moisture, accompanied by moderate air temperatures, relatively high humidities and many hours of sunshine, result in the development of abundant and vigorous shoots, which is the first requisite for heavy yield the next year. These factors also appear to be essential to the persistence and maintenance of healthy dark green cane foliage. The raspberry area in Pierce County, Washington, is probably a leader[323] because of the relatively high air humidity, moderate growing season temperatures, high percentage of sunshine in summer, and the rather liberal supply of soil moisture.

Deep rest of the Latham occurs in mid-October and is broken by early

December in Minnesota. Declining temperatures that break the rest also cause rapid development of cold resistance. Severe injury occurring after mild spells shows that cold resistance is quickly lost. Several specific factors in the hardiness complex need to be recognized. "If the term 'hardiness' is used merely to indicate survival it lacks value. If 'hardiness' means a high degree of cold resistance this factor has been present in the Latham raspberry for 30 years or more. It is apparent that objectives in breeding for 'hardiness' in raspberries should include in addition to a high degree of ultimate cold resistance and ability to harden rapidly, factors such as (a) retention of cold resistance once attained, (b) longer rest or deeper dormancy in order to avoid out-of-season-bud activity, and (c) ability to reharden if initial cold resistance is lost."[73]

PLANTING*

Time of Planting

Tip Plants. In northern regions, the best time to set tip plants of black or purple raspberries is in early spring, just as soon as the soil can be well prepared. It is usually better to set the plants early, even if the soil is not well dried out, than to plant late, because the plants start growth early.

Stage of growth of black and purple raspberry plants is important in relation to time of spring planting. The growing points that give rise to new canes are easily injured. Plants grown in a region with a comparatively early spring or on light soil are more advanced at a given date than those in a region with a somewhat later season or on heavy soil. This should be borne in mind when ordering plants. With black raspberry plants set after having been for some time heeled-in, stored, or shipped late, instead of a limited number of strong new canes a comparatively large number of rather spindly ones may result. It is hazardous, however, to set plants shipped after the leaves appear; also, anthracnose infection may have started.

Various dates were preferred as the average planting time for the black raspberry in Maryland,[82] ranging from late March to early May. However, the date on which the plants were set was less important than the condition of the plants when set. Of 107 growers, 49 preferred dormant stock, 45 preferred to wait until the

* The soil is prepared much the same as for grapes, strawberries, or general farm crops.

rooted tips had made 3–6 inches or even more of new growth before digging and transplanting; 10 preferred either dormant plants or those with three or more inches of growth, as against those with 1–2-inch sprouts; two preferred plants with short sprouts; and one preferred either dormant plants or those with short sprouts. The strong disapproval of plants with only short sprouts arose from the fact that such sprouts are easily broken in handling. When this occurred the plants usually died. When care in handling was used and the plants were set immediately after digging in equally good soil, either method gave good results. It was agreed that plants purchased from a distance should be dormant.

In the South, in Tennessee[184] for example, tips of the shoots of dewberries, Young, and Boysen root in the fall, and root growth occurs whenever the soil is warm enough during the winter. For this reason, it is best to set the new plants in late February or early March. The tip plants will have better root systems at that time. On the well-drained soil recommended for vineberries, there is usually more moisture in the ground in the early spring than later and a large percentage of the plants will live. In California, planting should be done not later than February or March, in order to receive the benefit of the late rains.

Plants from Suckers or Root Cuttings and Transplants. Red raspberries and blackberries are set successfully in early spring. In general, early spring is better than fall planting in regions with severe winters but the reverse is true in regions with mild winters.

Fall planting, in any region, especially with an experienced grower, is successful with red raspberries, blackberries, and transplants of black and purple raspberries. In fact, with these kinds, fall planting sometimes results in better success than does spring planting, particularly when adverse weather or other factors prevent early spring planting. Planting in the fall saves time in the spring when other matters are demanding attention. Also, the plants often may be moved from the nursery in the fall to better advantage than in the spring. There is less danger of the roots drying out in transit and handling, because drying winds and warm days are less common than in the spring. Soil preparation often can be done more thoroughly in the fall.

Red-raspberry plants purchased from nurseries in the fall are freshly dug; whereas plants purchased in the spring may have been stored throughout the winter under none too favorable conditions, especially when one nurseryman buys the plants from another. Ordinarily, late is better than early fall planting; late October or early November is a good

time in northern regions. Optimum time for fall planting, however, depends on the weather. With too early planting, drought and relatively warm days may reduce the stand. Plants set too late may not become sufficiently established to resist heaving out.

Plants set in the fall in northern regions can be afforded protection by plowing a furrow, with the soil turned toward the plants, on each side of the row or by mulching. Though ordinarily 12–18 inches of the red raspberry cane are left in planting, some growers prefer to trim the canes back to 6–12 inches and others to two buds above ground (see Setting the Plants).

Choice of Plants

Black and purple raspberry plants from tip portions placed in the soil in late summer or early fall are the best for spring planting. Transplants cost more than tip plants, anthracnose infection is often severe, and their value in comparison with tip plants is questionable for general purposes.

Red-raspberry suckers that have completed a strong growing season are best for commercial planting. Suckers of the blackberry are also used but root cuttings which have grown a year or two in a nursery row are preferred.

Distance of Planting

Blackcaps and Purples. Good spacing for black and purple raspberries is $2\frac{1}{2}$–4 × 7–9 feet. As a rule, the smaller the planting, the closer the plants should be set. Other things being equal, the more strong canes there are per area, the higher is the yield. Though high yield is very important, it does not tell the whole story. Where plants as well as fruit are sold, increasing the spacing between the rows facilitates tip-layering. Where a disc is drawn by a team or tractor, the distance between the rows should be greater than where cultivation is done by single horse. With a cultivator such as the Planet Jr. an eight-foot spacing requires three trips to cultivate a "through"; whereas six feet eight inches require only a round trip. Some large plantings where both tip-layering and fruiting are practiced have been set $2\frac{1}{2}$ × 9 feet. Ordinarily, the spacing is 3–$3\frac{1}{2}$ × 7–8 feet. Reducing the spacing in the row has accompanied an increase in that between rows in order to maintain a high number of canes per acre. Relatively close planting reduces wind breakage, but this is perhaps best offset by more

A planting of black raspberry in the summer of the first year. The spacing is $2\frac{1}{2} \times 6$ feet. An adequate space for tillage is needed between the rows, especially when the objects are to both harvest the fruit and to propagate plants by tip-layering. Spacing $2\frac{1}{2}$ feet apart in the row helps to offset the reduction in plants due to wide spacing between the rows and to provide an adequate number of plants per acre.

careful attention to low summer topping, production of canes of thick diameter, delaying the removal of canes which have fruited, use of supports, or certain other procedures.

REDS. Spacing 3–4 feet in the row and 7–9 feet between rows is suitable for red raspberries in hedgerows. The fact that the red raspberry is a prolific plant maker, fills the row quickly, and is comparatively long lived affects the spacing. (See also later under Hill System.)

In Washington,[300] rows of reds are spaced about seven feet apart, with the plants $2–2\frac{1}{2}$ feet apart in the row, though the distance varies somewhat with the soil fertility and moisture.

BLACKBERRIES. Good spacing for blackberries in the East is $3–3\frac{1}{2} \times 8–10$ feet.

In California,[248] blackberries of an upright habit, such as Lawton, are usually set 4–5 feet apart in rows 6–8 feet apart. Trailing varieties like Mammoth and Cory are planted 8–16 feet apart in rows about eight feet apart. Himalaya makes a rank growth and is spaced about 20 feet apart in the row. In Tennessee, 6×8 feet is recommended for the vineberries. In Oregon,[49] common spacing for Boysen, Young, and Logan plants is 8×8 feet. In California, the rows of these kinds are spaced eight feet apart, with the plants 5–6 feet apart in the row.

DEWBERRIES. The hill system, 5×5 feet, is commonly used for dewberries in North Carolina. In New Jersey, if the canes are to be trained in

solid rows, the plants are usually set three feet apart in rows 4–6 feet apart; in Michigan, $2\frac{1}{2} \times 7$ feet.

Pollination

The varieties of raspberries and blackberries commonly grown in northern regions are self-fruitful. They produce good crops in fields planted to only one variety. There is evidence[271] however, that benefits from suitable provision for pollen transfer, both in increased yield and to some extent in perfection of fruit, are such that bees can be placed to advantage in or near the raspberry field during bloom.

Even the hardiest of the trailing types of brambles when grown in northern regions produce a high proportion of imperfect berries.

Some blackberries or blackberry-dewberry hybrids, such as Rathbun, Mammoth, McDonald, Wilson, and Cazadero, are not completely self-fruitful under certain conditions[168] and should not be planted alone.

Table 34

Influence of Pollination by Insects on Fruit Setting in Raspberries. Michigan[271]

	Fruiting Shoots (*No.*)	*Blossoms* (*No.*)	*Blossoms Failing to Set Fruit* (*No.*)	(%)	*Berries* (*No.*)	*Imperfect Berries* (*No.*)	(%)
Cuthbert red raspberry							
Insects excluded by a cage	25	487	354	72.6	133	57	42.9
Insects not excluded.....	25	431	147	34.1	284	8	2.8
Cumberland black raspberry							
Insects excluded by a cage	22	182	18	9.8	164	36	21.9
Insects not excluded.....	22	176	..	..	176	3	1.7

Setting the Plants

One hundred per cent stand in planting raspberries or blackberries is the exception rather than the rule. The average is probably not more than 75 per cent of a stand, especially with raspberry plants shipped from a distance. The loss is chiefly due to carelessness.

The plants should be set at approximately the same depth as they grew previously, or slightly deeper. If set too shallow or if the soil is not well firmed, many of the plants may dry out. Such factors as poor root develop-

ment, heaving out, weak plants, injury from drought, and blowing over of the canes may also occur. If set too deep, the growing points may not push through the soil, especially if it is heavy. Occasionally it is advisable to set two plants together, particularly with red raspberries, small cuttings of blackberries, and with other types where there is poor root development or where the roots are partially weakened.

Raspberries and blackberries are usually set with a spade or in a furrow. A furrow is made for each row, the plants are placed in it, and the roots are covered with soil. After placing plants in the furrow or hole, it is often advisable to pack soil around the roots and sprouts by hand before filling in. This enables the soil to be firmed with a minimum of damage to the tender growth.

The "handle," "tail," or woody cane of a tip plant is of some convenience in planting and in locating the plants. But, this handle may be a

A portion of the parent cane accompanies tip-layered plants from the field. Anthracnose may be brought to the new planting unless this infected "handle" [center] is removed before the new growth (*left and right*) comes through the ground.

source of anthracnose infection and at planting should be cut off, leaving none of it above the ground. The plant suffers no ill effects from this treatment provided it is done early. If, however, removal of the handle is delayed until after growth is well started, not only may infection of the young first-year canes have taken place but the plant may be appreciably weakened by loss of food reserves. Furthermore, plants may be weakened before planting through partial drying out, heating, and various other causes. If the plants are thus weakened, a higher percentage stand and better initial establishment may result if the handles are not pruned off. In brief, if the plants are thrifty and are planted early, there are decided advantages in cutting off or burying the handles immediately after setting. But, if the plants are weak or are set very late in the spring, it may be best to leave the handles on, and control anthracnose by spraying. Some prefer to remove the handles before planting; this is satisfactory unless a cultivation is needed before the plants mark the rows. Any growths from the handle that produce berries should be removed, or the plant will be weakened; also, if the growth is only of this kind, the plant is unlikely to survive.

Strong red raspberry canes may be headed back to about 18 inches at planting, and less vigorous ones more severely. Measures for anthracnose control at planting as suggested for black raspberries are necessary with reds only in a few regions. In some regions, as in Minnesota, severe pruning of nursery plants is sometimes done to reduce mildew. A poor stand of reds often results when the canes are pruned back to ground level at planting, especially with plants set late in the spring when pruning causes appreciable loss of food reserves.

TILLAGE

Cultivation is the usual method of field culture for bramble fruits. (See also Mulching.)

Plowing the "middles" or discing, preferably the latter, is usually needed early in the spring. Frequent tillage during spring and early summer is desirable. Cultivation, especially near the plants, should be shallow. When roots are cut, even though the cut ends heal, the injured area may become infected with crown gall.

The following outline for raspberries is typical of the method often followed in southwestern Michigan and in regions with similar conditions.

Plowing is done, with one horse, about May 1, a back furrow turning the soil to the middle of the row. This, together with some hand hoeing during the succeeding two weeks, cleans up weeds and trash near the plants. About June 1 to 15, the soil is plowed up to the rows of plants; this provides some support for the canes. The plowing often consists of a single furrow and is followed by discing, or the entire space between the rows may be plowed. Some discing, harrowing, or cultivating is done during June and up to just before harvest when the plants occupy most of the space between the rows because of the bent position of the canes due to the weight of fruit.

Cultivation is sometimes done after each picking to loosen the soil packed down by the pickers. Disadvantages of this are that many berries may be knocked off in cultivation and those on the bushes may become dirty. Several hand hoeings are usually needed each year.

In most fields it is probably best to cease tillage soon after harvest to permit good ripening of the wood and for cover crop growth. Tillage usually extends later into the year when both plants and fruit, instead of fruit only, are the objective.

Where the soil is heavy and drainage none too good, many growers practice ridging black and purple raspberry rows. Rows of reds should not be excessively mounded during the fall and left that way over winter, or the buds that form new canes may be produced so high above ground that the new plants are weakened the next year.

In Pierce County, Wash.,[52] red raspberry growers usually plowed twice, first towards the plants in February or March and then away from them in March or April. The depth varied from 3–8 inches. The two highest yields were in fields which had always been cultivated deeply, a practice that would be damaging in a field where shallow cultivation had been practiced first. Subsequent cultivations made use of various types of cultivators and varied in number from 4–10 during the growing season, at an average depth of 2–4 inches. There was a correlation, in cases of growers giving the most cultivation, between frequency and yield; 77 per cent of the growers ceased cultivation when picking started; 18 per cent cultivated at least once after harvest.

MULCHING

Some advantages of a mulch compared to cultivation are: higher yields of berries in many cases; conservation of more soil moisture; prevention of

Black raspberries, straw mulched. (Courtesy, W. P. Judkins, Ohio Agr. Exp. Sta.)

erosion; easier control of weeds; more vigorous cane growth; reduced heaving of plants which results from freezing and thawing of soil in late winter and spring; lower and more uniform soil temperature in summer, which is particularly important in regions to the south. Some objections are: the labor required to apply it every year, and the cost of material if bought; danger from fire, mice, and, special need for nitrogen fertilizer for a few years after mulching. Mulching is likely to interfere with producing plants for sale. Mulching is not advisable on soils that lack good underdrainage because of waterlogging with excessive rains.

The addition of carbonaceous organic materials to the soil may bring about these effects: tie up the available nitrogen supply for a time; produce acidic and toxic substances; increase the soil aggregation; and improve the nutrition of the crop because of the nutrients contributed by the mulch and the conservation of soil moisture.

In Oregon,[50] neither fir nor alder sawdust (three inches deep when settled) had changed the acidity of the underlying soil after 18 months. The straw, hay, and walnut leaves (six inches deep) in the process of rotting produced a slight alkalinity, due to the liberation of bases in the process of decay and so decreased the acidity. A raspberry planting which had been mulched with straw for 10 years produced high yields. Also, the

mulch greatly improved the soil aggregation and slightly improved the organic matter content and fertility.

The phenomenon of potassium fixation at or near the soil surface when applied as a potash fertilizer can be practically eliminated in orchards where a mulch is used,[308] and this is significant also in small-fruit plantings under a continuous mulch. The fixation of potassium in such form as to be unavailable to plants is due to the combined effects of two actions: the effect of free alumina in forming muscovite or some closely related mineral which contains potassium in an unavailable form, and the result of alternate wetting and drying of the exchange material containing potassium thus causing the latter to be held in an unavailable form. In the Ohio orchard work, when 10 pounds of potash as 60 per cent KCl were added to a heavy mulch the soil to a depth of one foot was greatly increased in exchange material within three years. Within four months of the start of such treatment, soil to the depth of eight inches was increased in available potassium. In no other known way, except by mechanical placement, can potassium be increased to such a degree.

Table 35

COMPARISON OF RESULTS FROM RED RASPBERRIES UNDER CLEAN CULTIVATION, HAY MULCH, SAWDUST MULCH AND SOD, KENTVILLE, NOVA SCOTIA[283]

Treatment	*Yield per Acre (pt.)*	*Av. Cane Height (cm.) Viking*	*No. Canes per Acre*	*Yield per Acre (pt.)*	*Av. Cane Height (cm.) Newburgh*	*No. Canes per Acre*
Clean cultivation	2,467	155	24,200	2,950	101	13,309
Hay mulch	3,179	180	31,630	6,098	121	20,223
Sawdust mulch	4,025	170	41,140	6,132	129	36,644
Sod	604	94	1,383	104	77	980

A year after applying a hay or sawdust mulch to red raspberries a significant increase over clean cultivation occurred in yield, average cane height, and number of canes per acre at Kentville, Nova Scotia, Table 35. Sod ranked very low. One of the factors that promoted better growth and yield under the mulch treatments was the increased moisture content of the soil, Table 36. At some periods the water content, at the depth of

one foot, under the mulches was two or even three times as great as under cultivation.

Table 36

PERCENTAGE MOISTURE UNDER CLEAN CULTIVATION, SAWDUST MULCH, AND HAY MULCH AT KENTVILLE, NOVA SCOTIA[284]

Date	*Clean Cultivation*	*Sawdust Mulch*	*Hay Mulch*
June 26	16.4	18.0	18.0
July 3	15.5	16.0	18.0
July 10	13.9	15.0	16.2
July 17	10.4	14.2	15.0
July 24	8.8	11.7	14.4
July 27	7.6	11.7	14.1
July 29	7.4	11.2	13.3
August 2	5.0	9.0	11.2
August 6	4.5	11.0	15.8
August 8	4.3	11.2	15.9
August 10	8.6	13.2	15.9
August 19	9.5	12.7	15.6
September 5	11.2	13.9	15.5

Occasionally, with sawdust from evergreens, there is a toxic action on the plants due to such wood constituents as essential oils, resins, and tannins. With sawdust from deciduous trees,[190] an unfavorable action on growth is due to a lack of nitrate in the soil. Certain kinds of wood decompose more slowly than others, and hence their injurious effect is noted for a longer time. The lack of nitrate is due to a reduction rather than to an inhibition of nitrification, and this reduction is caused by a group of organisms which make use of cellulose. In course of time the plants will resume thriftiness, and the use of nitrogen fertilizer along with the mulch is a helpful procedure.

WINTER PROTECTION

In severe climates, as in Colorado, even red raspberries, the hardiest of the brambles, need winter protection, especially if not well sheltered by windbreaks.

COLORADO.[80] The best way to protect canes from winterkilling is to cover them completely with soil to a minimum depth of 4–6 inches. Straw, cornstalks, manure, and similar materials are sometimes used, but

none of these is as suitable as soil. Winds tend to blow coverings of these materials away, and they may harbor mice which cause damage to the canes. Deep snow does not always provide enough protection because the canes often are not entirely covered and the part above the snow is usually injured. This top portion often includes the most productive part of the canes.

Raspberry canes should be covered between October 15 and November 15. Fall pruning should be completed before the covering is done, and all two-year wood is removed close to the ground. It is better not to tip the canes in the fall but to wait until they are uncovered in the spring. After the canes have been pruned, they are covered in three operations. First, they are bent down as flat as possible without breaking and are weighted down at the right side of the row, so that the ends are not plowed into in uncovering as would occur if they were placed on the left side.

Then, one or two furrows about six inches deep are plowed on both sides of the row to throw soil on the canes. This will not completely cover them, and so it is necessary to finish covering with shovels. The canes should be covered 4–6 inches deep at their highest point. Often the tips of the canes will be covered several inches deep whereas the basal half or third of the cane may be only adequately covered. This does no harm. Canes should not be covered when they are frozen, because they are then so brittle that it is almost impossible to bend them to the ground without much breakage. Even under the most favorable conditions some canes will break. It often helps to remove a shovelful of soil from in front of the hill before the canes are bent down, especially in old plantings where the hills may be rather root-bound.

The canes should be uncovered in the spring before the buds swell much. If the canes are left covered until the leaves push out, there is great danger that they will be killed if frosts occur after uncovering. Leaves that grow before uncovering are tender and succulent and are unable to withstand even moderately cold weather. But, if the canes are lifted before growth starts, the leaves will come out gradually and become hardened to the prevailing temperatures. Canes uncovered early, when the buds were swelling but before the leaves had started to push out, have withstood 4.8° F. without injury.

The canes are partially uncovered by plowing down both sides of the

row, throwing the soil away from the plants. Then the canes are usually lifted by thrusting a four- or six-tine fork under them and lifting upward with a shaking movement. This pulls the tips from under the soil. The soil is then raked out from between the canes and the row left level, otherwise a ridge will form in a few years and make adequate irrigation difficult. Some growers do not uncover the canes completely at one time but plow away the sides of the ridge and then wait a few days before completely uncovering them, thus allowing the canes gradually to become acclimated to air temperature. There is little advantage to this practice.

MINNESOTA. In the Minnesota Fruit Grower, September, 1943, Dr. W. G. Brierley makes this report. In a number of plantings, 50–200 plants were tip-covered during the last week of October. This method was followed as less labor was required than for complete covering with soil. The canes were bent over to the ground as close as possible without breaking and enough soil shovelled over the tips to hold them down. In the spring the canes were lifted before the buds started and the effects of protection noted in early June. In every field the tip-covered areas stood out in sharp contrast to the unprotected areas. In half the test fields the protected canes showed no injury at all and were alive to the tip buds. In other cases there was slight injury to the cane tips, but the injured portion ordinarily would have been removed in tip pruning in the spring. In some cases some of the buds in the arched-up portion of the canes had been killed, but the same injury had occurred in the unprotected parts of the fields where it appeared to be more extensive.

In the tip-covered plots as a whole the average injury did not exceed 5 per cent. In the unprotected portions of the same fields injury varied from 10 to 80 per cent and averaged a little over 40 per cent. As there was so little injury to the tip-covered canes and so much to those not protected the value of protection was demonstrated beyond question. When the fields were examined in early June it appeared likely that cane injury would reduce the crop 40 to 50 per cent in the unprotected areas whereas the protected plants probably would produce nearly a full crop. Tip-covering can be done quite rapidly and the labor cost is very moderate compared with the market value of that portion of the crop lost by winter injury.

Covering may be done over a period of several weeks, with the canes in full foliage, without running into difficulty. In fact, the leaves serve as

effective anchors to hold the canes down. It is recommended that covering be done in October. The work can be done later but risk of soil freezing is greater.

Since Latham canes quickly lose their cold resistance it would seem that winter covering with soil may avoid injury more by protecting the canes against warm weather than against cold.

IRRIGATION

Although irrigation may be a means of saving or increasing the yield of fruit and production of plants, there are few raspberry or blackberry fields in the East under artificial irrigation, as most growers seem able to get along without it. Because aphids, anthracnose, and mildew may be more prevalent if overhead irrigation is practiced frequently, surface methods may prove superior in many cases where water must be applied. On the other hand, overhead irrigation may be most helpful in checking red spider. Irrigation is a standard practice in certain areas in the West.

COLORADO.[50] The frequency with which raspberries should be irrigated depends on the weather and the physical character of the soil. In years of much rainfall, plantings naturally will require less irrigation. Showers seldom wet the ground deeply enough to provide water for the root systems and cannot be depended on to take the place of irrigation. Heavier types of soil, such as silt and clay loams, are more retentive of moisture than are lighter types, such as sandy loams, and require less frequent irrigation. Likewise, soils high in organic matter are more retentive of moisture and require fewer irrigations than those lacking in humus. The latter take up water slowly and are difficult to irrigate. The furrow system of irrigation is used.

Soon after the plants are set, shallow furrows are made a few inches from one side of each row and a small stream of water run through them until the soil is thoroughly wet around the roots of the young plants. From then on, the grower must rely on his own judgment as to when to irrigate. In any case, a thorough irrigation should be given at least every two weeks; some soils require water more frequently.

In the picking season, large amounts of water are needed for the fruits. Two thorough irrigations a week during harvest are sufficient except on very light soils. The fruit should be picked in the morning of every other day. On irrigation days, the water is turned in as soon as picking is over

for the day. This allows the surface soil to dry before the next picking. When pickers must work in a muddy field, the soil becomes packed, hard, and difficult to cultivate.

From about August 15 on, irrigation should be only frequent enough to keep the plants from suffering from lack of water. This, combined with the reduced frequency of cultivation, checks the rapid growth of the plants and causes them to mature their wood before winter and to store food for the next year's crop.

In the fall just before the plants are covered for winter protection, the plantings are irrigated thoroughly so that there is plenty of water in the soil to maintain the plants during winter. This irrigation also makes the soil easier to handle when covering the plants. Even if winter protection is not necessary, it is desirable to give this irrigation to keep the soil from drying out during winter since many plants may be lost by the roots dying in dry soil.

In irrigating, the water is run long enough to wet the soil at least one foot deep. The more thorough the irrigation the less frequent the need for its application. Some growers irrigate frequently, yet their plants suffer from a lack of water simply because they do not irrigate thoroughly enough.

CALIFORNIA.[248] Water is applied every two or three weeks until the berries begin to ripen. Then the frequency is increased, sometimes to every 4–7 days. After picking, the planting is irrigated every four weeks until late in the season, when the plants are allowed to mature. The water is applied in furrows on both sides of the row. This leaves a middle portion between the rows which remains dry and provides a place for the pickers to stand. If a large head of water is used, the furrows are large, 200–300 feet long, and laid out on a grade nearly level. The furrows are filled level full with water. When a smaller head of water is used, the grade is sufficient to permit the water to reach the lower end, and the water is allowed to run for a longer time. Often, the row becomes wide and filled with canes because of the unchecked growth of suckers, and the central portion is not wetted by the ordinary irrigation. During hot weather, bush berries use a tremendous amount of water, most of which is taken from the upper two or three feet of soil. Exhaustion of this moisture is soon shown by wilting of leaves and shriveling of fruit. Lack of moisture during the growing period shortens the picking season and reduces the crop.

OREGON.[249] In the Willamette Valley, the berries from irrigated plants averaged larger in size than those from the dry plots, as follows: Evergreen blackberry, 30 per cent; red raspberry, 7 per cent; Logan, 35 per cent; black raspberry, 22 per cent. Irrigation materially increased the cane growth. A larger portion of the irrigated Evergreen blackberries ripened in the earlier part of the season than of the

fruit grown from the non-irrigated vines; with red raspberries the time of ripening was not retarded, but with Logan it was slightly retarded by irrigation. The quality of the canned red raspberries was fully as good, that of Logan was improved, and that of black raspberries was not materially affected by irrigation.

FRUIT-BUD FORMATION IN THE BRAMBLE FRUITS

In New York[311] black raspberry flowers differentiate in late fall, probably in early October, and before the purples and reds. Flowers of the blackberry differentiate late in August; little change takes place between September and March. All buds of raspberries are potentially flower buds. The basal buds of the blackberry may be leaf buds and are more often entirely vegetative than those of the raspberries. Some raspberry varieties fruit in the fall at the ends of the current year's canes and so the vegetative shoots are not determinate but may or may not form fruit buds according to conditions.

In Oregon the terminal buds of Latham differentiate in September, the buds 50–60 inches from the base in November, and those 30–40 inches from the base in February.

The first visible evidence of flower initiation in Latham in Iowa[116] is a broadening and flattening of the floral axis in buds late in April. Discernible flower initiation occurs some time after bud expansion in the spring.* At this time the most advanced buds on the cane, i.e., those in which differentiation is evident, have produced shoots about an inch long, and at the same time some buds have scarcely broken. These retarded buds show no evidence of floral structures until after they have produced small shoots. Frequently, differentiation is discernible in the most advanced buds on the cane three weeks earlier than in the retarded buds on the same cane. Apparently some buds irrespective of position on the cane remain in a vegetative condition much longer than others. Except for the irregularity just described differentiation occurs in the acropetal order on the cane.

With respect to autumn-fruiting it has been noted[136, 197] that vigorous plants fruit earlier and better than weak plants. Furthermore, spring, summer, and fall fruiting in the raspberry are responses to day length and temperature. The tendency to form fruit buds begins earlier and develops faster in the terminal buds of the canes as soon as they cease to elongate

* Flower initiation on fall bearing shoots of Latham apparently occurs shortly before blossoming.

rapidly. These terminal buds rapidly develop fruiting laterals which flower and fruit. Lower buds do not begin so soon and do not develop into flowers until next spring. In all reds, fruit-bud formation is most rapid in the terminal buds and least rapid in the basal buds. Ranere which forms fruit buds earliest and in the longest days of summer is followed by Lloyd George, whereas Cuthbert does not form fruit buds until early autumn.

Latham, Chief, Viking, and Newburgh do not begin fruit-bud formation until so late that usually no flowers appear until spring.

USE OF FERTILIZER ON THE BRAMBLE FRUITS

Responses from the Use of Fertilizer on Blackcaps

Michigan. The yield of fruit from canes and of branches and likewise the size of berry are closely correlated with diameter of cane.[269] The largest and most vigorous canes produced the best crop. Yields of individual shoots and likewise the average size of their berries were closely correlated with the amount of foliage. This indicated the importance of cultural methods that promote vigorous growth and development of good foliage and that protect it from injury.

Blackcap canes 0.46 inch diameter produced an average yield of 6.58 ounces; whereas 0.65 inch canes yielded 12.47 ounces.[273] An illustration was given of the fruiting capacity per acre of two types of plants: with seven canes per hill left for fruiting, averaging 0.47 inch diameter, it was about 3,200 quarts; whereas, with four canes left per hill, averaging 0.43 inch diameter, it was 1,120 quarts.

The foliage of Cumberland rows fertilized with sulfate of ammonia in spring or in September was a rich dark green.[322-323] That of rows fertilized after harvest was a little lighter in color. The checks and those which received phosphorus in the spring or nitrogen when the berries were turning red produced yellowish foliage, and some of the leaves of the fruiting laterals were more or less bronze in color. Plants given nitrogen in early August, September, or in the spring, tended to outyield the checks, the plants which received phosphorus, or those fertilized with nitrogen when the berries were turning red. Nitrogen, in a quickly available form, applied in mid-September, resulted in an increased early-season yield. Some increase also resulted from applications made about August 1 or about the time that growth starts in the spring.

Successful culture of the black raspberry is dependent to a very large

extent on the physical rather than the chemical condition of the soil, particularly for total yields.[254,478]

OHIO. Sulfate of ammonia was applied on black raspberries at rates of 100, 200, 300, and 500 pounds per acre in early spring.[255,256] The fertilized plots outyielded the checks, and about one third more fruit was produced from the sections that received 300 pounds of fertilizer than from those that received 100 pounds. The full measure of value of the fertilizer could not be taken until at least the next year, because the canes are grown one year and the berries produced the next. The second year, the 300-pound plot led in fruit and vigor.

Fertilizing heavily with nitrogen has enabled a grower to maintain, on a sandy soil, a black raspberry field which was still productive when 12 years old, even though it was nearly 90 per cent infested with crown gall.

The roots were found to be most numerous at 18–24 inches from the plant.[244] There was a gradual reduction in number of roots of all sizes as the distance from the plant was increased, and a sharp reduction at about three feet from it. This indicates that the rows could well be closer than nine feet if economy of space is an important factor. In the placement of fertilizers under similar conditions, it would seem that along the sides of the rows and to a distance of 2–3 feet outward is most economical.

INDIANA. Yield and size of berries were closely correlated with diameter of cane.[94] Highest yields were secured when nitrogen was used with phosphorus or sulfate of potash. All three elements increased yields over the checks if used in sufficient quantities. Sugars tended to show higher values in plots receiving sulfate of potash.

NEW YORK. In the Bristol area, nitrogen gave a profitable return, even on what might be considered a quite productive soil.[129]

RESPONSES FROM THE USE OF FERTILIZER ON REDS

MICHIGAN. Red raspberry canes 0.31 inch in diameter produced an average yield of 4.0 ounces; canes 0.43 inches, 7.5 ounces.[273] Very large, naturally branched canes 0.62 inch in diameter, averaged 12 ounces.

RHODE ISLAND. Potash proved as important if not more so than nitrogen, and phosphorus the least important.[351] Since phosphorus is important in growing cover crops and these are very important in supplying humus where barnyard manures are scarce and also since the element is relatively cheap it seems advisable to use all three elements.

WEST VIRGINIA. The use of 300 pounds of nitrate of soda per acre on a soil of a poor to medium fertility increased the yield of Latham.[98] No consistent advantages of spring over fall application, or vice versa, were shown. Much of the increase resulted from greater wood production in the fertilized plots, number of canes being the outstanding factor.

OHIO. The yield and vigor was greatly increased by nitrogen fertilizer (sulfate of ammonia, 250 pounds per acre). The results were influenced by the fact that canes produced in a given year do not bear fruit until the next year. In the third year of the planting (first year of fertilizer application) only a slightly increased yield resulted, but the increase in vigor of canes for the next year's crop was pronounced. In the fourth year, three unfertilized rows (each 84 feet long) produced 49.2, 101.9, and 85.9 pints, respectively, or a total of 237.0 pints. The fertilized rows adjoining each check produced 113.2, 131.8, and 120.5 pints, respectively, or a total of 355.5 pints. Also, in the fertilized rows the fruit on the second-year canes was larger and of better appearance, the first-year canes were more vigorous and with greener foliage, and prospects were better for a high yield in succeeding years.

WASHINGTON. Fertilizer carrying 3 per cent nitrogen, 10 per cent phosphoric acid, and 7 per cent potash (3-10-7) usually gives satisfactory results.[300] Where cane growth is unsatisfactory a 6-10-7 fertilizer, which contains twice as much nitrogen, may be better.

ONTARIO. Nitrate of soda, 300 pounds per acre, increased yields in a comparatively cool moist season but 600 pounds per acre decreased yields in a dry season.[160] Superphosphate, 750–1200 pounds per acre, did not give significant results. This particular soil was already moderately well supplied with readily available phosphorus. Sulphate of potash, 480 pounds per acre, increased the yields. The soil was rather low in replaceable potassium.

GENERAL RECOMMENDATIONS ON FERTILIZER

The planting should be well supplied with humus. Seldom is this matter given the attention it deserves before planting. It is much easier to provide a liberal amount of humus before planting than to try to add it after planting. After planting, however, a suitable cover crop may be sown each year soon after picking is completed. The best cover crop to use depends on the soil and locality, but, so far as possible, an annual legume should be used. The situation is more complicated where both fruit and

plants are sold than where only fruit is sold. Applications of manure are beneficial when made in a red-raspberry field during the winter, but this cannot be done conveniently with the black raspberry until the long branches have been shortened or the tip plants dug.

Applying nitrogen fertilizer to black raspberries a month after planting. The more vigorous the canes, especially from a diameter standpoint, the larger will be the yield the next year.

A number of experiments has shown that diameter of cane is correlated with yield. In most fields the first-year canes are not so vigorous as desired. Since there is, in general, a correlation between vigor and yield, practices promoting vigorous canes early in the season are advised. Judicious use of fertilizer in most cases increases yield and vigor. The more vigorous the plants, the more fruiting wood they can support to advantage. Also, the greater the number of vigorous canes per acre the higher is the yield, and, at the same time the greater the need for a highly fertile soil.

An annual application of 250–300 pounds per acre of a nitrogen fertilizer, such as nitrate of soda or a corresponding amount of other material, early in the spring is recommended in general for fruiting brambles. It may be applied near the plants both between and in the rows by hand or be drilled in. If applied directly on the crowns it may cause injury.

Annual use of sulfate of ammonia results in the soil becoming somewhat more acid. In a Cumberland planting at Wooster, Ohio, where annual applications of 250 pounds per acre of sulfate of ammonia were made over a five-year period, the soil reaction dropped from about pH 5.3 to 4.8, which is too acid for example, for best results in growing sweet clover as a cover crop without liming. But the raspberry plants produced high yields in the fifth year.

There may be some justification for claims that use of quickly available nitrogen fertilizer makes the fruit softer, particularly red raspberries. How

ever, black raspberries receiving the suggested rate of nitrogen have been trucked a good distance to market and have arrived in excellent condition. It certainly seems true that many raspberry growers, including red raspberry growers, could beneficially use more nitrogen than has been their custom.

In Missouri,[310] a late-summer crop of oats with an early fall application of nitrate of soda resulted in the highest degree of hardiness produced by any treatment. An early fall application of nitrate of soda without a cover crop did not increase hardiness. A late summer crop of oats alone caused a degree of hardiness less than that of the plot with cover crop and nitrate.

The need of cane fruits for phosphorus, potassium or lime does not seem to be generally as imperative as that for nitrogen. Use of these substances, however, is a safety measure, and they can nearly always be used to advantage when cover crops are grown. To obtain proper growth of cover crops, it may be advisable to apply lime and about 200 pounds per acre of an 0-14-6 fertilizer broadcast between the rows just before the last cultivation. If nitrogen is not included in the spring it should be applied at this time. Split applications might be the best plan in some cases. Applications that promote late growth which is subject to winter injury should be avoided. There is some evidence[32] that the color, texture, and flavor of packed raspberries is best when phosphorus and potash occur with nitrogen in the fertilizer.

Though the use of fertilizer frequently is helpful, it does not completely offset a poor stand of plants, poor drainage, disease and insect damage, or many other factors. The judicious use of fertilizer should accompany other good cultural practices.

SYSTEMS OF TRAINING BRAMBLE FRUITS*

Systems for Black and Purple Raspberries

Black and purple raspberries are maintained in the original crowns in the rows. Though trellises and supports possess certain advantages, wires or stakes are not ordinarily necessary with properly pruned black raspberry plants. Many growers who formerly used supports have abandoned the

* See also Pruning.

One method of supporting black raspberries by means of wires. The young plants are tied to a single wire. In future years, support will be provided by the addition of a second wire which will be stretched along the other side of the row and tying will not be practiced.

practice, largely because of the cost and the adoption of low summer topping. The yield the year after planting is higher and the berries are cleaner when supports are used. As good a method as any is one in which one wire is stretched along the row after a year's growth and the canes tied to it. The wire passes over nails in the interior posts and is readily let down in later years when removing old canes. The second year another wire, similar in all respects to the first, is erected to extend along the other side of the row, but the canes are not tied. The height of the wires is 18–24 inches.

Two rather distinct black raspberry areas occur in Washington County, Md. Northward from Boonsboro, most plantings are in hills, with a five-foot stake for each hill, and an average of slightly over 2,000 plants or "canes" per acre. Southward from Boonsboro, the row system is used almost exclusively. As the stakes rot off at the point and loosen, they are straightened and redriven each year before tying the new canes. This leaves 3–4½ feet of stake above ground. With the row system, sometimes heavy, well-braced posts are set at the ends of the rows, and stakes are driven every 40–50 feet. In other cases, stakes are used throughout, the heavier ones at the ends and the intermediate spaced 15–25 feet. Adherents to the hill system advance these claims: Greater freedom from weeds in the planting through cross-cultivation; greater ease in picking and in transferring filled baskets across to certain rows for collection; less nursery stock required per acre, yield about equal or nearly equal to a similar sized row planting. Opposed to these are the advantages as seen by growers preferring the row system: Larger number of plants per acre, resulting in a higher yield from the same land, lower cost of trellis material, less washing of land than when cross-cultivation is practiced.

Systems for Red Raspberries

Raspberries send up shoots from the leader buds which usually are formed at the base of the old canes. Sometimes only one such bud is produced on each cane, but usually at least two are formed, and sometimes three or more appear. Thus, if two canes grew the first year after planting and each produced two buds, four canes would appear the second year, eight canes would be formed the third year, and by the fourth year there would be 16. However, some of the buds do not start and many of those that do start make weak canes, so that when plants are in bearing about the same number of strong canes are produced the first year after the planting comes into full bearing as during each following year.

Besides producing canes from the leader buds, red raspberries send up shoots called "suckers" from their underground stems. If some system of training were not used a red-raspberry field would soon become a dense thicket of canes, each competing with others for food, moisture, and light, and the berries could be picked only with difficulty.

Hedgerows. Reds are commonly grown under a system in which suckers are allowed to develop between the plants in the row and so form a hedgerow. The wide hedgerow, which is often 2–3 feet wide, though probably outyielding other systems, has several marked disadvantages. The fruiting shoots in the center of the row are crowded and many die prematurely, berries are overlooked by the pickers and are either lost or picked later when overripe, weak canes are produced which bend over and allow the berries to get dirty, and fungous diseases dependent upon moisture for their incidence may be more severe on the shaded canes in the middle of a wide row.

A better quality crop is obtained by restricting the row by cultivation and pruning to a width of 1–1½ feet (narrow hedgerow). In this system the rows are 7–8 feet apart, or more if a tractor is used for cultivation. Because of the large number of canes to the acre greater yields are possible than with the hill system, and because of the narrowness of the row, the faults of the wide row are eliminated.

A good method for reds grown in hedgerows is to use a series of posts placed in the center of the row and one or two wires strung along each side of the row. The wires are drawn together slightly by means of short cross wires. The support may also consist of one wire, to which the canes are tied, for each row. It seems best, unless very windy, to support tall red

Red raspberries trained in hills (the canes are tied to stakes). Plants have been trained to this system on large acreages in the Midwest.

raspberry canes in hedgerows by a wire trellis rather than to prune back too severely.

LINEAR SYSTEM. In this system, which is used on the Pacific Coast, only the original plants are kept for fruiting and the suckers are removed. A minimum of hand-work is necessary with this system. The new canes are thinned when the second hoeing is done in early summer. At that time a large part of the surplus canes are easily removed before they have grown large. This practice conserves the plant vigor and makes picking easier.

HILLS. The staking of red raspberries in hills is the preferred method in southern Illinois, and in a few other regions. The plants are set 6 × 6 feet, sometimes two in each hill, especially where the stock is not so desirable as it might be. Stakes are usually set in the beginning of the second year; 5–8 canes are tied to each stake, depending upon the vigor of the plant and the soil fertility. Two or three ties are made, pulling the canes close to the stakes, so that the fruiting laterals tend to grow outward and are not entangled with the canes, thus making picking easier. Since the areas in which the hill system prevails are largely shipping areas, clean picking is very important in avoiding spoilage of the berries. The pruning height varies. Most growers cut back the canes at the time of spring pruning and tying to about the height of the stake, or about 5 to 5½ feet. Some have left the canes longer, but in windy weather much injury is done to the succulent fruiting shoots. Others have tried topping the reds and find that the laterals when they do grow are difficult to tie to the stake and the flowering shoots emerging from these laterals are quite easily broken as the fruit increases in weight while ripening.

The *teepee-hill system* does not require stakes. About 5–8 canes far enough apart to make the base of the hill 15 inches wide are selected. They are drawn together at the top and tied tightly. Two ties are necessary; the first is made as near the top as possible and the second about eight inches lower. Unless properly made the teepee hill tends to twist and fall over. To avoid this, make the hill with a wide base, shorten the canes to four feet, and tie very tightly. The yield is somewhat lower than with staked hills, keeping the hills free from grass and weeds is a little more troublesome, but the inconveniences and cost of stakes are eliminated.

In the *hillrow system* plants are set about three feet apart in the row. Hillrows are kept within the confines of the original hill and at about 8–10 canes per hill. This system is used to some extent in Colorado and a few other places where canes are laid down and buried. Wires running along the row may be used to support the canes during the growing and fruiting seasons.

Systems for Erect-growing Blackberries

A number of systems are used for training erect-growing blackberries e.g., (a) summer topping, with or without wiring or staking; (b) tying to a single wire about $2\frac{1}{2}$ feet aboveground or slightly higher if not summer topped; (c) supporting the canes, without tying, by a wire stretched along each side of the row; (d) tying to two wires about three and five feet aboveground. No one system is adaptable to all conditions.

Systems for Trailing Types[497a]

The grower must choose between a stake system or a wire trellis and erect it usually in the year of planting.

Stakes. The canes are gathered together and tied at several places to stakes 5 to $6\frac{1}{2}$ feet high. Any ends protruding above the tops of the stakes are cut off.

Sometimes a cross arm is nailed to the top of the stake. This arm may be from 1 to 2 feet long. Canes are tied with two or three ties to the stake. Where the cross arm is used, the canes may be looped over the arm and the ends of the canes cut off.

Training to a Single-wire Trellis. A heavy wire is strung very tightly on posts 16 to 20 feet apart. The wire is usually 5 or $5\frac{1}{2}$ feet aboveground. The canes are taken up and twisted along the wire in either one

or both directions from the plant. The ends of the canes may or may not be cut off. Canes of Boysen, Logan, and Young plants, when set from 8 to 12 feet apart in the row, need to be left 9 to 12 feet in length for training.

One of the objections to this method is that many canes are wrapped together around a single wire. Unless a very heavy, tightly stretched wire is used, there is danger of its breaking down. Breaking down may also occur if canes are not properly tied to the wire. However, the high single-wire trellis gives more room for hoeing and training-back operations and all the berries are in one place for the pickers.

TRAINING TO THE TWO-WIRE VERTICAL TRELLIS. The two-wire vertical trellis is probably the most common of the trellises used. Cedar posts are set from 16–24 feet apart along the row. Large posts may be set farther apart and smaller posts or stakes set every 10 or 12 feet between. The end posts are well anchored or braced. Two wires are stretched between posts, the upper wire about $4\frac{1}{2}$–$5\frac{1}{2}$ feet aboveground and the lower wire about two feet below the upper one.

Various methods of attaching the wire to the posts are used. Large staples or nails are often used, but these sometimes pull out under a heavy load of fruit. One solution is to stretch the upper wire along the top of the posts. The wires may also be passed through holes bored in the posts or rest in notches cut into the side of the posts. Wires usually need restretching each year before training. The method of attaching the wire to the end posts should be one that will allow tightening of wires each year.

There are various ways of training canes to the two-wire trellis.

WEAVE OR WREATH SYSTEM. In the weave or wreath system, a few canes, usually one to three, are taken together and passed from upper to lower wires and back again to form circles or wreaths. All the space between the wires is utilized in this system. Sharp bends or curves causing damage to canes are avoided. More time is consumed in training with this method than with some of the others described here.

LOOP SYSTEM. In the loop system, the canes from a single plant are divided into two parts and each part is taken separately to the top wire, one or two twists around the wire are made and then the cane is brought down to the lower wire and turned back toward the plant with one or two twists. The excess length of canes is usually cut off when they reach the upright portion of the canes. The other half of the canes is looped on the other side of the plant in a similar manner, thus forming a double loop.

Canes can be trained quite rapidly to this system. Plantings using this system appear very uniform and attractive.

HALF LOOP OR INTERLOCKING SYSTEM. The half loop or interlocking system is similar to the loop system except that the canes are not turned back toward the plant. Instead they are brought down to the lower wire and interlocked with the canes of the next plant. The portion of the canes left at the point of interlocking is cut off. Canes about nine or 10 feet long are left in this system when plants are set about eight feet apart.

ROPE OR FOUR-ARM SYSTEM. The rope or four-arm system is obtained by dividing the canes into four parts and extending them along both wires. Usually the longer canes are taken to the top wires. Canes may be cut off and tied at the point of intersection with those of the next plant or interlocked with them. This method usually requires more time in training than the two loop systems.

A variation of this method is quite practical in handling the Brainerd blackberry and other vigorous varieties having a similar habit of growth. This system consists of pinching off or cutting the terminals of the new canes just after they have reached the top wire. Strong lateral branches will then be produced below the point of cutting very similar to those of the black raspberries. These lateral branches may then be trained along the upper and lower wires at the time of training. Some branches coming out at right angles to the row may have to be cut off as these canes cannot be bent without breaking them.

FAN SYSTEM. The fan system consists of bringing up individual canes to the wires in the form of a fan. The canes are tied to the wires or sometimes interlocked and twisted along the upper wires. Much tying is usually necessary in this system.

TRAINING TO THE HORIZONTAL TRELLIS. The vigorous varieties, such as Evergreen, Himalaya, and Mammoth, are often trained on two horizontal wires on which are placed crosspieces of wood or wire to support the canes. There are also various systems of handling the canes on these trellises.

TWO-WIRE HORIZONTAL TRELLIS. The two-wire horizontal trellis is a system in which 2 wires are supported on crosspieces nailed to the posts. These crosspieces are from 1 to 2 feet in length. Other crosspieces of wire or wood are laid on the wires and the canes are placed on them. Placing the crosspieces both above and below the canes will hold them in place

quite securely. In this system the wires are about 4 to 5 feet aboveground.

FOUR-WIRE HORIZONTAL TRELLIS. The four-wire horizontal trellis consists of two pairs of horizontal wires, the lower pair placed about two feet below the upper pair. When a trellis of this type is used, the new canes of the current season are not allowed to grow along the ground. If the fruiting canes are placed on the upper wires, the new growth is trained along the lower wires. These canes may be either taken up to the upper wires after the old canes have been removed or left to fruit on the lower wires. In this case the new canes are trained up to the upper wires where they remain until after they have fruited.

PRUNING BRAMBLE FRUITS

Raspberry and blackberry pruning is grouped here under three headings; namely, summer topping, removal of canes which have fruited, and heading back canes and branches while dormant. Pruning at planting is discussed in the section on *Planting*. Destruction of undesirable plants between the rows is distinct from the other operations. Thinning of plants in the row is considered in the general pruning treatment.

SUMMER TOPPING

Proper summer topping is one of the "secrets" of success in the profitable growing of black raspberries without wires or supports. Summer topping of the terminal canes is advised when black raspberries are 18–24 inches high. This checks the terminal, encourages strong branching, results in a low, stocky plant, and harvesting is facilitated the next year. Such plants are best able to withstand damage from high winds, and the need for a trellis, which is a considerable item of expense, is avoided. Strong branches are produced which are capable the next year of bearing heavy yields of high quality fruit. Low stocky plants are by far the best for tip-layering.

The field should be gone over several times in order to top the first-year canes at the desired height. It is not necessary and, in fact, may be somewhat harmful to remove only the extreme tips because the top lateral may extend more or less as an upright terminal with a narrow-angled weak crotch, which is unduly subject to breaking. A better plan is to pinch or cut the main cane 3–4 inches or slightly more from the tip. This causes a wider angled, and therefore a stronger, union or crotch. Because of the

presence of fruiting canes, topping is more difficult in established plantings than in young ones. It is practically impossible to keep up with the work without the topping of some canes that have become tall. When most of the canes have been left unchecked until late in the year, the best procedure may be to make the best of an undesirable situation and support them by wires to avoid wind damage. Late topping is likely to prevent the development of branches which are long enough to root at the tip. This is a drawback in propagation, and this type of cane development is not an advantage even for the fruit crop.

A uniform height of checking the first-year canes can be obtained by waiting until all become higher than 18–24 inches and then cutting them back at one time. This also avoids the confusion which arises after the field has been gone over three or four times and the earlier topped canes have branched and their tips are difficult to distinguish from those on unchecked canes. But, when canes become higher than three feet the topping tends to produce growth mostly from the weak buds. It seems better to top the tall canes severely rather than to leave them tall without support, providing the work is not done so late that the new growth is damaged by low temperatures.

Summer topping is advised for black and purple raspberries and under some conditions for blackberries but not for red raspberries. Shears may be used in place of fingers.

Summer topping of the terminal shoots of the erect blackberry, when practiced, is usually done when the plants are 24–30 inches high. Heading back vigorous branches of the first-year canes while in leaf facilitates picking but its effect on future yield and growth is undesirable.

The use of small shears rather than the fingers or knife avoids sore fingers. In fact, when the canes are neglected for a few days after the proper time for topping, it is difficult to remove the terminal portion with the fingers.

Summer topping of reds should be avoided as most tests have shown appreciable damage.

Removal of Canes Which Have Fruited

The canes of bramble fruits are biennial; that is, they complete their growth in height the first year, bear fruit the second, and then die. The underground stem system is perennial, sending up a new crop of canes each year.

After the canes have fruited in the summer they should be removed; whether soon after the fruit is picked or at the time of early spring pruning is optional. On the one hand: canes which have fruited are of little further value in the field; their early removal permits next year's canes to grow without obstruction; the field looks better; cutting out and burning them soon after harvest may destroy some of the diseases and insects and red spider present; the canes are less tough and easier to remove at this time; there is little or no loss of food supply in the roots; in large propagation fields, removing the second-year canes soon after harvest avoids tramping on the tip-layered plants; diseases can be detected more readily in inspection work; blowing over of canes is not necessarily most serious in fall or winter; supported canes maintain their position well irrespective of when the second-year canes are removed; cultivation is facilitated; leaving the second-year canes in the field over winter does not protect the first-year canes from low temperatures; rush of other work is often less pressing at this time than in the spring.

On the other hand: the second-year canes, under some conditions, protect and support the first-year canes against breakage by storms and heavy weight of snow when drifted; the amount of disease controlled by destruction of the second-year canes soon after harvest is usually negligible; the second-year canes do not appreciably obstruct the growth of the first-year canes; the first-year canes mature a little earlier than otherwise.

Removing the second-year canes soon after picking is usually the best practice.

Indications were noted with Latham in Minnesota[36] that in dry seasons or when the plant grew in soils lacking an adequate water supply, removal of the second-year cane immediately after harvest conserved for the plant the water which would be transpired by this cane from that time until the end of the season. Further, with copious rainfall and an excess of soil moisture which delayed the maturity of the first-year canes, leaving the second-year canes in place until the end of the

season tended to reduce the excess of water, and they then served to supplement the action of a cover crop and possibly to hasten the maturing of the first-year canes. Transpiration was more rapid in the second-year canes until about the end of the harvest season (last picking August 7). On August 11, the rates in the first- and second-year canes were about equal. On August 18, the transpiration rate was greater in the first-year canes, and this relation persisted until the end of September. There was a significant decline in the rate in the first year canes after August 11. It began somewhat later in the first- than in the second year canes, but the rate of decline in one closely paralleled that in the other.

Little difference was found in Minnesota[29] in the transpiration rate of the first- and second-year canes of Latham until late in the season. However, the second-year canes generally had a much larger foliage area so the total volume of water used was greater for them, at least during July and early August. The earlier decline of the foliage on the second-year canes might have accounted for the relative falling off for these canes both in total volume of water transpired and in the rate per unit area.

Histological studies[30] of the canes of the red raspberry showed that cambium begins to decline in meristematic activity in the first year and is relatively feeble in second-year canes. Apical meristem ceased to function at the end of the first year, no new winter buds were formed the second year, and cambium in the second-year cane formed relatively small amounts of new xylem and phloem elements. Both first- and second-year canes increased in diameter in the central and tip regions in the second year, but in 90 per cent of the second-year canes there was no measureable increase at the base. Cambial activity, as shown by the formation of new xylem, probably occurs in nearly all growing canes in the second year, being comparatively feeble and related to the vigor of the laterals (fruiting shoots) rather than to the vigor of the cane in the first year. New xylem formation was not observed in the second-year canes until the fruiting shoots had developed several leaves. Cambial activity progressed downward slowly from the point of bud insertion and was generally limited to the same side of the cane on which the shoot was growing. The easy breaking of fruiting shoots is ascribed to this limited development of new xylem. However, where fruiting shoots were numerous there was noted a general activity of the cambium with the formation of a complete though narrow ring of new xylem. Cambial activity in the second year was limited in some cases to the maturity of the phloem initials cut from the cambium late the first year and to an increase in radial diameter of the remaining cambial cells. Degeneration of the phloem at the base and tip of the canes occurred at about the same time, the former being associated with senility of the cambium and the latter with unsatisfactory water supply.

After harvest there is a decided upswing in the curve of total sugars which indicates that the foliage on the second-year cane is still active photosynthetically but that the photosynthate is not transported out of the old cane system. This checks nicely* with the earlier findings that the phloem of the second-year cane breaks down at the base soon after harvest. Such a breakdown prevents the downward movement of carbohydrate material. However, under satisfactory nutritive

* Correspondence with W. G. Brierley, University of Minnesota.

conditions, it is doubtful that the phloem breaks down immediately after harvest. --"I have repeatedly observed in Colorado that the base of the cane was the last to dry up. In Latham it was very common for 4–6 inches at the base of the cane still to be green when the fall pruning was done about November 1. The rest of the cane was dead and dry long before that time."*

Further work with Latham in Minnesota[61] has shown that removing the second-year cane soon after harvest results in a longer period and greater growth of the first-year canes and some possibility of the plant utilizing in the growth of the first-year canes the water and mineral foods which otherwise would have been taken up by the second-year canes.

In still further work in Minnesota,[67] it was noted that callus over-growth and accumulation of sugar in artificially girdled canes occurred at the time of most rapid growth in the new canes. These and other studies of the behavior of the red raspberry relative to possible competition between fruiting canes and new growth do not make it appear likely that any competition that may exist is harmful to canes of either age. More likely the relationship is a cooperative one. At the time the fruiting laterals are growing rapidly it is probable that food stored in the canes and roots may be transported upward and used to promote growth. When the fruiting laterals have about finished their growth and a large foliage area is forming photosynthate in excess of the needs of the fruiting canes, the surplus may be transported downward for use or storage in other parts of the plant until translocation of sugar is prevented by the normal senescent breakdown of the phloem.

In the Puyallup Valley, Wash.,[296] a spike-tooth or spring-tooth harrow and a horse will remove the second-year canes from between the rows of an acre of raspberries and bush blackberries in a few hours. A small, home-made one horse bull- or sweep-rake is sometimes used for the same purpose. Since canes of the trailing type are longer and harder to handle, they are usually bunched on a hay fork and carried to the ends of the rows.

The Tiffany or short-handled pruning tool is commonly used to cut the old canes just above ground level. The ordinary hand pruners require more stooping or kneeling but permit good work at reasonable speed.

Heading-back Dormant Canes and Branches

Optimum Period. The regular dormant pruning is best done in late winter or very early spring. It should be completed before growth starts or spray material is applied. Buds that have swollen are easily broken off in pruning. Pruning is inconvenient when the soil is soft and muddy and during adverse weather. March is probably the best time in northern

* Correspondence with R. V. Lott, University of Illinois.

regions. If too early pruning is practiced the canes are likely to be brittle and to break easily, and, when cut back to the proper lengths, subsequent winter killing or drying out of the end portions may unduly reduce the amount of fruiting wood left. The various types of raspberries are pruned

Pruning the black raspberry after a season's growth. Before pruning (*top*) and after pruning (*bottom*), the branches being trimmed back to 6 to 8 inches in length.

differently for best results and are not pruned the same as blackberries. The amount of pruning necessary varies with the type, variety, vigor, and other growth conditions.

Sometimes it is the best plan to delay pruning of the erect blackberry until the fruitful and unfruitful flower clusters can be distinguished. Then, if it is seen that the fruit is to be borne relatively far out on the branches, pruning should be comparatively light. Shortening such branches too

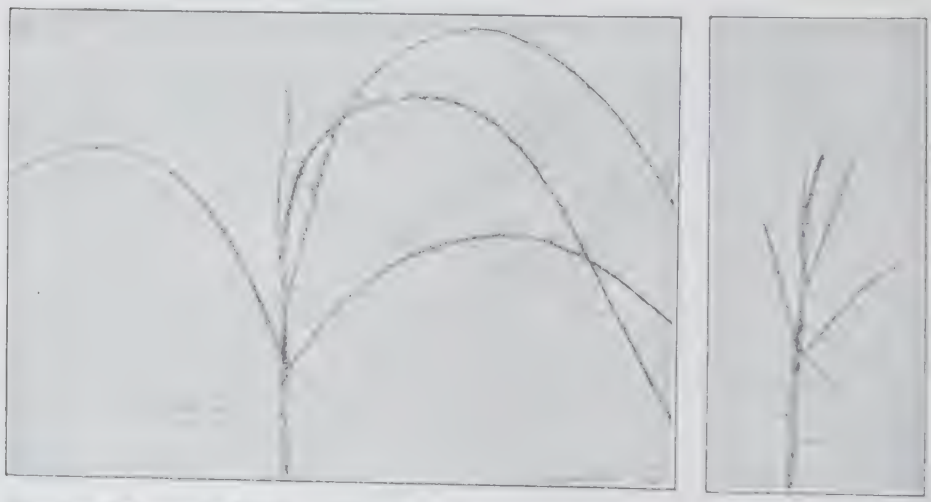
much would reduce yield. Buds of the black raspberry are forced into fruiting more readily close to the main cane than are those of the blackberry.

In pruning, the shears should be so manipulated or the cut wood so handled that the prunings fall away from and not on the plants where they become entangled and their removal is difficult and leads to destruction of buds.

Dormant Pruning of Black Raspberries. This is concerned mostly with branches, as nearly all terminals are, or should be, eliminated by summer topping. Most terminals encountered in the dormant pruning of black raspberries are weak and should be cut off just above a strong branch. Pruning may also be concerned with thinning canes in the hills, especially those which are slender.

In general, pruning tends to decrease the number of berries and to increase their size. In fact, at times, with the black raspberry, increase in size of berry offsets the decrease in numbers and results in little difference in marketable yield, particularly in dry seasons or on soils of inadequate fertility.

Four general types of pruning have been followed with the black raspberry in Washington County, Md.,[382] arranged in the following order of importance: First-year canes headed at 2–3 feet in summer and laterals tied up and cut off near the top of the stake in the spring; canes headed at 2–4 feet with laterals cut to 6–8 inches when tied; canes headed at 2–4 feet with laterals cut to 3–4 inches in the spring; and, canes headed high or not at all, with the laterals removed in the spring.



Pruning the mature black raspberry, the branches being trimmed back to 8 to 12 inches, or in accordance with the vigor.

Shortening the branches of unsupported plants to 4–7 inches the first year and to 8–12 inches in mature fields usually gives the best correlation between size and number of berries when the plants are vigorous and healthy. But, condition of the canes and whether or not support is used may justify more severe or more lenient pruning. The more vigorous and healthy the cane, the more fruiting wood it can usually support to advantage. This must be considered when increased growth results from use of fertilizer. Too much fruiting wood, unless soil fertility is high, may reduce the number of canes developing for future years. Weak, slender canes may well be removed, but excessive thinning of strong canes should be avoided.

One way to increase yield is to increase the amount of fruiting wood per acre, that is, by leaving longer branches when pruning or by producing and retaining more canes per acre; in the red raspberry a greater height of cane is also involved. In a vigorous Cumberland black raspberry field at the Ohio Station (with branches left 6–12 inches long) retaining up to 10 canes per hill for the third, fourth, and fifth crops did not result in a decrease in the succeeding number of canes in the same hill. Some reduction occurred in the number of canes, in their diameter, and in the yield of the sixth crop. In Michigan,[274] Table 37, yield increased in direct proportion to the number of canes in the hill, up to nine canes. Some soils may not be fertile enough to maintain 9–10 canes per hill properly. Certainly, however, in many fields it would be profitable to build up soil fertility and regulate pruning so that more than 4–5 canes per hill can be maintained annually. In many cases it would be wise to increase the number of canes left per hill and to shorten the branches more than is the custom.

With respect to the number of blackberry canes per hill or per foot of row, many factors, particularly vigor of growth and habit of growth, are involved; for example, in comparison on a hill basis slightly fewer vigorous first-year canes need be retained with the blackberry than with the black raspberry because a longer length of branch should remain after pruning the former. As to number of canes per foot of row, in comparing blackberries and red raspberries, slightly fewer canes should be retained with the blackberry because of its more branching habit.

Yields of the black raspberry were fairly closely correlated in Michigan[477] with planting distance, stand, and number of canes per hill. Heavy

yields were practically impossible with less than 3,000 fruiting canes to the acre, and maximum yield was possible only when there were from 5,000 to 8,000. Individual canes in thickly-stocked fields might be less productive than those in thinly-stocked fields, but yield per acre was greater with the larger number of canes. Close planting reduced injury from wind. Profits or losses in the field depended primarily on yield per acre.

Table 37

RELATION OF NUMBER OF CANES PER PLANT TO TOTAL YIELD. BLACK RASPBERRY. MICHIGAN[275]

Number of Canes per Plant	*Number of Plants*	*Average Yield in Ounces*	
		1929	*1930*
2	12	17.5	16.2
3	16	24.2	20.5
4	25	26.4	25.8
5	33	27.9	27.1
6	20	36.2	32.9
7	20	33.9	29.2
8	4	47.8	36.2
9	5	49.8	42.8
10	4	40.2	40.5

DORMANT PRUNING OF REDS.* The canes are of two types, those that develop from buds at the base of the old canes, and suckers that develop at a distance from the crown. Certain varieties, e.g., June and Marlboro, sucker rather sparingly, whereas others, e.g., Cuthbert and Newburgh, produce many suckers. Unless the many suckers are periodically reduced in number the planting soon becomes a dense thicket of little value for a commercial crop.

The red raspberry should not be summer topped. The pruning is concerned mostly with unbranched canes.

In Colorado,[311] the highest yielding buds of a cane were found in the third, fourth, and fifth foot sections, Table 38. Therefore, bud distribution may be added to the factors which determine yield, including weight per berry, number of berries per fruit shoot, and percentage of bearing buds.

* See also remarks for Newburgh, under Varieties.

These factors, probably excepting the last, are varietal characteristics. That bud distribution is an important varietal characteristic was shown by the fact that a consistent increase of only one bud in either the third or fourth foot section would give, in productive sorts, an increase of about 20 grams per cane or 300 quarts per acre in a linear hedgerow with an average of $2\frac{1}{2}$ canes per foot and rows eight feet apart. When the canes were headed to three feet, two of the three heavy producing sections were removed, viz., the fourth and fifth. In order to benefit from such heading, the three remaining feet must make a yield increase greater than the yield from the fourth, fifth, and sixth feet. Such fruiting response did not occur. Cayuga and June canes headed at four feet yielded[312] less than at five feet. Yield per cane and percentage of bearing buds were greater in three- than in five-cane hills. Grams per berry, grams per bearing bud, berries per bearing bud, percentage of bearing buds, and length of fruit shoots were not significantly influenced by cane heading at four feet in comparison with five feet.

It is recommended for reds in Colorado:[313] (a) in hills, all vigorous canes, up to a maximum of 10 canes, should be left in the dormant pruning; (b) a moderate cane heading should be given to remove winter-injured wood and the inferior berries which are produced near the tips of the canes of small-fruited varieties; (c) those cultural methods should be practiced which promote vigorous cane growth; and (d) those varieties should be selected for commercial production which have a relatively uniform bud distribution, high yield per bud, large berries, a vigorous habit of growth, and resistance to disease infection.

In Michigan,[279] 62 per cent of the buds on a Cuthbert red raspberry cane produced shoots that matured their fruit; 10 per cent remained dormant; 12 per cent grew into vegetative, unfruitful shoots; 10 per cent winterkilled, chiefly at the tips of the canes; a few buds developed into shoots that were mechanically injured; and a few produced weak shoots that later dried up. Numbering from the base of the cane, the first five buds were moderately productive and the tenth to fifteenth ranked second. From the fifteenth bud to the tip of the cane, the average yield of the laterals progressively decreased. Size of berries decreased gradually from the base to the tip of the cane. Much higher yields were obtained from large canes than from those of small diameter. Naturally branched canes were larger, more vigorous, and more productive than unbranched ones.

Table 38

PERCENTAGE INCREASE IN NUMBER OF BUDS WITH INCREASE IN HEIGHT. COLORADO[311]

Ht. in ft.	Cayuga		Cuthbert		June		Latham		Lloyd George	
	No. of Buds	% Incr.	No. of Buds	% Incr.	No. of Buds	% Incr.	No. of Buds	% Incr.	No. of Buds	% Incr.
3	25.1	..	18.4	..	22.6	..	25.6	..	25.8	..
4	33.2	32.3	25.4	38.0	32.4	43.4	33.3	30.1	34.7	34.5
3	25.1	..	18.4	..	22.6	..	25.6	..	25.8	..
5	41.2	64.1	34.4	87.0	41.6	84.1	40.9	59.8	43.5	68.6
3	25.1	..	18.4	..	22.6	..	25.6	..	25.8	..
6	49.9	98.8	44.6	142.4	50.6	123.9	49.2	92.2	52.5	103.5
4	33.2	..	25.4	..	32.4	..	33.3	..	34.7	..
5	41.2	24.1	34.4	35.4	41.6	28.4	40.9	22.8	43.5	25.4
4	33.2	..	25.4	..	32.4	..	33.3	..	34.7	..
6	49.9	50.3	44.6	75.6	50.6	56.2	49.2	47.8	52.5	51.3
5	41.2	..	34.4	..	41.6	..	40.9	..	43.5	..
6	49.9	21.1	44.6	29.7	50.6	21.6	49.2	20.3	52.5	20.7

The first five buds on the branches gave rise to a number of vegetative or barren shoots; the tenth to fifteenth buds produced the best yielding laterals. Beyond the fifteenth bud, yield and size of fruit decreased rapidly. Summer topping resulted in branches being formed that were very susceptible to winter injury and markedly reduced yield. In general, thinning of canes greatly reduced the yield without increasing the size of berry, but probably not more than 10 canes to four feet of hedgerow should be left. In hills, eight canes per hill gave the best results. Light heading back of the canes resulted in an increased total yield over no pruning; severe heading back greatly reduced the yield. There was no marked increase in size of fruit due to heading back, except in a dry season. Canes lightly headed back were the easiest to harvest. The dense foliage of the new shoots and the fruiting canes made harvesting more difficult after severe pruning. Unpruned canes were often top heavy and bent over into the cultivators. The main portion of the cane should be lightly headed back and the

branches shortened to about 15 buds or 10 inches. Somewhat heavier heading was warranted where the moisture supply is limited.

In Minnesota,[57] though vigorous Latham canes may be expected to produce in proportion to the length of cane, the yield often is affected by certain factors: (a) Laterals (fruiting shoots) grow more vigorously as pruning increases in severity.* (b) Canes pruned short increase in height proportionally more than longer canes because of longer laterals. (c) Canes pruned to 60 inches bloom and produce ripe berries a few days earlier than canes pruned more severely. (d) The taller canes yield slightly more fruit in the early pickings. (e) Canes pruned to 36 inches or less yield slightly more fruit in the late pickings than do 60-inch canes. (f) These slight differences in early or late yield do not materially affect the seasonal distribution of the yield, and low pruning does not greatly lengthen the fruiting period. (g) Drought and unusually hot weather reduce the size of berry and yield. Rainfall, even light showers, may immediately increase the size of berry and yield for one or two pickings. (h) Size of fruit is smallest from the 60-inch canes and becomes larger from successively shorter pruning, due, in part, to the effect of pruning and, in part, because size of fruit normally decreases toward the tips of the canes. Severe pruning removes most of that part of the cane where small berries are produced and, in affecting the vigor of the remaining laterals, may increase berry size. (i) Increase in size of berry is inadequate to offset the loss in yield due to removal of the upper portions of the cane. (j) The size of berry is not related to the volume picked on any single date. (k) When other factors are not limiting, total yield is in proportion to length of cane. (l) Winter injury, drought, and high temperature can reduce the yield of the longer canes to about that of those pruned to 36 inches. (m) Heading to 15 inches is too severe and the increase in berry size is not enough to offset the heavy loss in crop volume. (n) As winter injury, drought, and high temperatures may affect yield as much as does height of pruning, cultural practices which tend to avoid these effects should be used.

Statements to the effect that severe pruning causes the development of longer fruiting laterals may have been based upon the *average* length which is definitely increased by the removal of the upper portion of the canes where the laterals usually are short. In Minnesota,[62] the trend towards

* See also next paragraph.

shorter laterals on the more severely pruned canes is apparent for the first two feet of the canes, except with canes pruned to five feet. The trend is in the opposite direction in the third and fourth feet of height, and is the result of severe drought and heat which was effective for five weeks prior to July 3, when the measurements were made. This supports the view that the performance of the cane as a whole depends more upon moisture supply than pruning treatment.

It is usually best to head back the dormant canes as lightly as is compatible with suitable training, freedom from damage in cultivation, ease of harvesting, avoidance of small berries near the ends of the canes, and other factors. Some growers make a point of not removing the tip portions as, even though these berries are rather small, they bring a good price because of their earliness. Probably it is better to say that a certain proportion of cane should be cut away rather than that the cane should be cut to a certain height irrespective of the amount of growth, and, in general, about one fourth is often the right amount to remove. Thinning out of small, slender canes in the hedgerow is usually desirable. Fruiting canes 6–8 inches apart, on an average, are usually well spaced in the row. Removal of too many robust canes reduces yield. Higher yields per acre are usual from hedgerows than from hills, but, with the latter, 5–10 of the most vigorous canes should be left per hill. The hedgerows should be kept fairly narrow. The best width of row, however, varies with the space between rows and other factors. The wider the rows the more berries that will probably be produced; but, when the rows become too wide, proper picking, tillage, and other practices are made more difficult.

Red raspberries are commonly trained by either the topping and tying method or the weaving method in the Puyallup Valley, Washington.[2] If the canes are short or stiff the former method is used. With canes six feet and longer, either may be used. In both systems the best 6–9 canes are saved. For each system the trellis consists of four No. 14 wires stapled to posts or short cross-arms. The lower pair of wires is two feet above ground and the upper pair two feet higher. Posts are set about 30 feet apart. Topping and tying consists of pruning the canes to about 5½ feet and tying to one of the top wires. The canes, tied in bunches of two or three, are trained in fan shape, by making the twine continuous from bunch to bunch. In the weaving method, the canes are woven to one of the top wires and in groups as in the previous system. They are brought up be-

tween the two top wires, bent over and out and down, and the tips tucked in behind the ones which are already in place. The operator works backward along the row. If the canes are too long or the tips dead they are then cut back.

With Cuthbert in Washington,[200] the weaving system produces earlier ripe fruit than does the topping system; also, the total yield is greater, but the berries average smaller.

In Pierce County, Wash.,[53] of 69 red raspberry growers, 10 per cent used the weaving method, 34 per cent the cutting and tying method, and the balance practiced both. The three highest yields were obtained from fields in which the canes were cut and tied, but this fact did not seem particularly significant in favor of that system. Both systems required about the same amount of time and one system might be preferable one year and the other might be better another year. The cut and tie method made clean picking easier. Training by either method was done in early spring, after the heaviest frosts were over.

Dormant Pruning of Purple Raspberries. The amount to shorten branches of purple raspberries depends much on the vigor of cane. Vigorous healthy canes can support more fruiting wood than can weak ones.

In Missouri,[165] 6.1 buds occurred on the basal eight inches of Cardinal purple raspberry branches as compared with 9.2 buds in black raspberries. Moreover, many of the buds near the bases of vigorous branches were poorly developed and either failed to grow or produced little or no fruit. Thus, to insure a heavy crop, fairly long branches were necessary. On small branches, especially secondary ones, however, the buds were close together and well developed. The number on the basal portion of such branches was practically identical with that for the black raspberry. In general, it seemed that purple raspberries should be left 18–24 inches long.

In northern regions, heading back purple raspberry branches to 6–10 inches the first year and 10–14 inches in succeeding years is advised.

Dormant Pruning of Erect Blackberries. Blackberry varieties vary more than black or purple raspberries in fruiting habits.

In Illinois,[109] blackberry varieties were grouped as follows: (a) Those with cluster buds near the base of the branches and well down on the canes, as Lawton and Ward. The fruiting clusters were rare on the five buds nearest the tip. The number of buds per branch was 8–12. Cutting back moderately, removing up to half of each branch, had little effect in reducing yield and facilitated cultivation and harvesting. (b) Those with the

buds nearer the tips of the branches and canes, as Early King, Taylor, and Wachusett. Close pruning of these reduced the crop materially. As a rule, the first 3–5 buds next to the main cane on each branch did not produce fruit. With an average of 15 buds per branch, enough were left for maximum yield if 5–6 buds, or one third of the branch, were cut away. Any unbranched canes remaining were cut back to five feet in height. (c) Those with buds scattered fairly well along the production wood, as Ancient Briton, Wilson, Ohmer, Eldorado, and Mersereau. The most vigorous and productive varieties were included here. Severe pruning was needed in this group more than in the other two. Many branches carried up to 18 buds each. These buds usually bloomed and so too many berries were produced to ripen properly and the fruit was small, seedy, and poor in quality. The best practice was to shorten the branches one-half, reducing the number of buds to 7–9.

In Missouri,[468] on the basal region of Early Harvest branches, an average of 6–8 buds was found and almost as many on branches of Robinson. On Snyder, Eldorado, Taylor, and Rathbun there were 4.5, 3.9, and 5.4 buds, respectively, or only about half the number on Early Harvest and Robinson. The number of buds increased slightly farther out on the branches, but about the same ratio was maintained between the two groups of varieties. With the second group, it was therefore necessary to leave longer branches or a greater number, since these varieties produced fewer branches. When possible, however, it was best to cut the branches comparatively short and leave a greater number, since very long canes with a heavy crop near the tip might split off from the main canes. In general, Early Harvest and Robinson branches were shortened to 10–15 inches and those of Eldorado and Taylor to 18–24 inches long.

In West Virginia,[95] the best yields were obtained where the laterals were pruned to 12-bud lengths and nitrogen was applied. The largest berries resulted from the addition of nitrogen to plots pruned to four-bud laterals. The nitrogen made the crop slightly earlier and increased yields in all cases except where the laterals were left unpruned. The increased yield was due to the production of larger berries and of either larger clusters or more clusters per plant.

Blackberry pruning should be modified according to the fruiting habit, vigor, and other conditions. The more vigorous the first-year canes, the longer the branches should be left. Shortening the branches in the dor-

(*Top, left*) Evergreen blackberry: fruiting canes on top wires; first-year canes to be trained on a lower pair of wires. (*Top, right*) Red raspberry: topping or upright system with 4 wires, one pair near top of posts and one pair below. Topped canes tied to one top wire. (*Bottom, left*) Red raspberry; "Weaving" system. (*Bottom, right*) Closer view of weaving system. (Courtesy, H. D. Locklin, Western Washington Exp. Sta.)

mant season does not seem to force the buds into fruit as much as with black raspberries. In some Ohio blackberry plantings moderate to severe heading back of branches in the winter has resulted in extending the season later than from light pruning or no pruning.

As a rule, branches of Early Harvest should be shortened more than those of Eldorado, and branches of Eldorado more than those of Blowers. For branches of Eldorado a length of 1½ feet and of Blowers around two feet or slightly more is usually suitable for mature plantings in northern regions. Undesirable branches arising close to the ground may be cut off at the main stem.

Dormant Pruning of Trailing Types.* Evergreen blackberries in Washington[296] may be trained by either of the methods described for red raspberries there. The trellis for both systems is made by stapling four

* See also earlier under Systems of Training.

No. 12 wires to cross arms, which are nailed to strong posts 16–18 feet apart. In the more common method, the second-year canes are placed on cross-strips between the two top wires. The top pair of wires is about four feet and the bottom pair two feet from the ground. Each winter the first-year canes are moved to the top wires to make room for the succeeding canes. With the overhead system, the young canes are trained to the top wires, and the second-year canes on the lower pair. The lower wires are about four feet from the ground and the top wires are 5½ feet high. With either system, the canes are woven over and under the cross-strips in a serpentine fashion. Of the two systems, the overhead results in less winter injury and a larger crop following severe winters. Ten or twelve good canes are left per hill. The canes are cut to be 13–15 feet long. Though the most common practice is to put the fruiting canes on the top wires and the young shoots on the lower wires, the young shoots will winter better if they are trained on the top wires with the fruiting canes beneath.

In the staking method, for dewberries and related types the canes are tied at two or three places, and when the tip is about 1–1½ feet above the top of the stake it is cut off, to check further terminal growth and force growth into the branches. Soon after harvest, the stakes are pulled up and the second-year canes cut out. Pruning the first-year canes to the ground reduces their number the first year but it helps control cane blight; and the destruction of all removed top growth, including the leaves, also aids in reducing anthracnose and other cane and leaf diseases. The first-year canes spring up quickly and are encouraged by the use of fertilizer and cultivation. They are allowed to lie on the ground until the next spring when the stakes are again driven into the ground and the canes tied to them.

In Tennessee,[184] in late February or early March when the buds first show color, about half the canes extending in one direction from the middle of the plant are picked up as a bundle and loosely tied either to a wire trellis or to a stake. The rest of the canes are tied to the trellis with the tips extending in the opposite direction. New shoots that grow from the crown after the fruiting canes are tied to their supports are cut off with a sharp hoe so as to get them out of the way of the pickers. After harvest, a sharp hoe can be used to cut away all old canes and new growth. The hoe must not cut deeply into the crown or the roots of the thornless Boysen or Young as new shoots are apt to be thorny. The old canes and shoots are carried off the field and burned, thus eliminating many diseases and insects.

The common practice with dewberries in southwestern Michigan is to train the canes on a single-wire trellis. The wire is stretched 2–2½ feet above ground on posts which are set 20–40 feet apart. Winter protection is provided. In the spring, the canes are shaken out with forks, gathered together in a bunch, and tied to the wire. In most cases, the ends of canes are cut off 8–10 inches above the wire.

HARVESTING AND MARKETING BRAMBLE FRUITS*

Pickers and Picking

The number of pickers required varies with the conditions of harvesting, more being needed at the height of the season and other rush times. The usual rate of payment for picking is one fifth the price received by the grower.

Picking a quart of black raspberries every 10–15 minutes of working time throughout the day is a reasonable rate. In Maryland,[382] 5–6 good pickers per acre are usually used. One grower with 5½ acres of Plum Farmer, which has a shorter season than Cumberland, used about 20 pickers. Usually about half of these were children and half adults. A 12-year-old child may pick 50–75 quarts in a 10-hour day, while an adult may pick 150 to 200 quarts. In Oregon,[49] pickers average 70.5 pounds of red raspberries per 8-hour work day. The number of pickers required for a given planting or for a district as a whole would be greatly decreased, or the acreage the available pickers could handle would be greatly increased, if full-day picking could always be practiced. Transportation facilities or weather conditions, however, are not always such that full-day picking is possible or advisable.

In many plantings, especially red raspberries, it is important that picking be done only in early morning; otherwise, the berries may heat up, bruise easily, and are hard to cool for marketing. In Colorado, 10–20 pickers, working from 5 a.m. to 10 a.m., are used per acre of red raspberries; picking is done every day at the height of the season. Black raspberries should also be picked early in the morning; picking in the afternoon of hot days adversely affects the appearance of the berries and the total yield because the berries dry up and become smaller.

The number of pickers available varies with the financial condition of

* Frozen-pack Preservation has been discussed under Strawberries.

Grasp raspberry lightly between thumb and two fingers and pull from the "core" with steady, even pressure. Do not use thumb and one finger.

the country. In 1932, a "depression year," about 200 pickers were used in a 12-acre blackcap planting in Ohio. They were paid 2c a quart, received their money weekly, worked only about half each day, and some of them drove about 30 miles to reach the planting. The early completion of daily picking enabled the grower to study the markets and the quantity it would seem best to deliver to various cities and towns. Many of the pickers took berries as part of their pay.

There is a growing practice in some regions for customers to do the picking themselves.* In this way, they save the cost of picking, and, as they may use any sort of container, they also save this cost. The grower does not need to hunt pickers, can sell crates to those who desire them, does not need to haul to market, and has cash in hand at the end of each day. The growers often have a "waiting list" of such customers and notify them when they may come and pick. This system of harvesting does not take much more management than to handle regular picking crews.

Careful handling for market is necessary. The berries should be picked directly into the box or cup in which they are sold and should not be handled for grading or sorting. Crates holding 16, 24, or 32 quarts, respectively, are used for the various types of berries. Red raspberries are often

* This is also true, as well, for the other small fruits.

marketed in pint boxes; in some sections in the west, the ½-pint box is commonly used.

Boxes are usually filled quickest with blackberries, followed in order by black, purple, and red raspberries. Some varieties are more tedious to pick than are others, for example, Ranere than Latham. The tall crop of Ranere is especially slow picking. When the crop is good, the berries large, and the canes well supported, a given measure can be filled practically as quickly with Latham as with black raspberries. The picking period of reds usually extends longer than that of the other kinds, tending in part to make harvesting more expensive. Because blackberries are the last to ripen and have spiny or thorny plants, a bonus is sometimes given to blackberry pickers who remain after the strawberry and raspberry crops.

In picking, waist carriers are more convenient than picking stands, but the berries are shaken up more. Waist carriers are supported by a strap or strong cord tied around the waist and usually hold two baskets. As soon as the baskets are filled, they are transferred to hand carriers or to crates and carried in them to the packing shed.

In California, in the Central Valley about seven pickers per acre are employed during the peak of the Boysen season. The entire planting must be picked every day or every other day during warm weather. In the Central Coast area and in Southern California, fewer pickers are required because the crop comes on more slowly and over a longer period of time. A good picker averages 200 pounds of berries per day. For fresh market the fruit is picked directly into half-pint baskets in a carrier or in a 12-basket crate. If the fruit is sold to a processor it is picked into a crate which is lined with paper or which contains a special cardboard liner. In a few localities in the Central Valley, the berries for the processor are picked into gallon cans and then transferred to crates which hold 10–12 pounds of fruit.

Stage of Maturity

Raspberries are ready to pick when they separate readily from the receptacle or "core." They should not crumble or fall apart. For shipping, picking of raspberries should begin when the fruit separates fairly easily from the stem, and the fruit is firm but well colored. Blackberries color to almost a full color before ripe. A good stage to pick blackberries is when the little depression in the center of each drupelet is entirely filled. Often

blackberries exposed to the sun after picking develop a bitter taste and a reddish color. Frequent picking is desirable, particularly for reds, as they deteriorate faster than do blackcaps or blackberries.

The Evergreen blackberry produces a firm fruit which is canned for use by the pie trade and to some extent as a dessert fruit. Commercially it is picked every 7–10 days. The Boysen and Young do not develop good flavor or full size until they are fully ripe. Then it is best to pinch the stem rather than the berry itself, to get it loose.

Conditioning Room

Growers who experience difficulty in getting berries to market in good condition, or who wish to improve the keeping quality of their fruit, may find it desirable to construct a conditioning room in which the berries may be placed as soon as they are picked. A room of this type provides for controlled ice refrigeration, circulation of air by an electric fan, and equipment to increase the natural CO_2 content of the air in the room. Refrigeration is controlled by a special damper so that the berries are not cooled below 48° to 50° F., at which temperature there is usually little or no condensation of moisture on the fruit when removed from the conditioning room.

This type of room provides ideal temperature and humidity for temporary storage. The circulating air removes some moisture from the berries, and so increases their firmness and improves their shipping quality. The added CO_2 replaces much of the oxygen in the room and thus slows down the respiration of the fruit. This is important because rapid respiration results in early deterioration of the fruit. The action of the CO_2 slows down respiration more effectively than can be accomplished by low-temperature refrigeration, and it also markedly retards the growth of mold. This makes possible the use of 80 to 90 per cent relative humidity without promoting mold development. The result is that the berries retain their freshness and brightness for many hours longer than usual, and they do not deteriorate so quickly when removed from the room as do berries removed during hot weather from ordinary low-temperature refrigeration.

Shipping Raspberries

For shipping berries fresh, the red raspberry planting should be picked every day. If the berries are to be canned or are to be preserved by the

frozen-pack method, every third day may suffice, unless the weather is exceptionally warm. In Washington,[300] red raspberries are divided into two grades: the "shippers," or berries which are large, firm, and in prime condition, and the "canners," or berries which are too soft to ship fresh but which are still in good condition for a lower price. When growers deliver to an organization which does not ship berries fresh, all the fruit is picked together as canners. The fruit should be delivered twice each day if possible.

The soft texture of the red raspberry has made necessary the working out of special methods to protect it against spoilage while in distant transit. When refrigerated express cars are used for shipping raspberries, these cars are equipped to bunker large amounts of ice and the cars are re-iced along the way. The berries are usually precooled before placing them in the refrigerated cars. Other means of shipping are refrigerator trucks and refrigerated freight in fan-equipped cars.

CONTROLLING BRAMBLE-FRUIT DISEASES AND INSECTS

Diseases Which Affect the Entire Plant and Cause Varying Degrees of Stunting

The virus diseases, curls, mosaics, and streaks, and the fungous disease, orange rust, are included in this group. These diseases are very destructive in their effects. The exact nature of viruses is not well understood, but they reproduce only in the living plant. They are transmitted from plant to plant by means of insects, chiefly aphids, and not by pruning or other cultural operations, except as these operations may spread the carrier aphids. Infected bushes never recover. All stock propagated vegetatively from infected plants is also infected.

Virus Diseases. Two types of *leaf curl* occur on raspberries. The "alpha" type is common on reds and cannot be transmitted to blacks. The "beta" type occurs on blacks and can be transmitted to reds. Curl is characterized by a downward curling of the leaves. The color of the curled leaves is deep green. In the first year the shoots may not be decidedly dwarfed, but those produced the second year may be only half the normal height, and by the third year they may be less than a foot high. The lateral fruiting shoots are dwarfed and the berries small and of inferior quality. The disease is spread by the very active plant louse, *Aphis rubiphila*. Purple

raspberries may be considered immune to leaf curls. Two black varieties, Plum Farmer and New Logan, seem never to become infected.

The mottling produced on the leaves of affected plants, and splotches of shades of yellow and green, which vary in size and contour, are the usual symptoms by which *mosaics* are detected. The crop suffers in yield and quality, flavor is lost, and the fruit crumbles and crushes easily. *Green mosaic* (green mottle mosaic, red raspberry mosaic, or red mosaic) is found on red, purple, and black raspberries. It is most serious in its effects on blackcaps but is more widely distributed on reds. Infected blackcap canes are retarded in development of foliage on their fruiting canes in the spring (see Isolation). *Yellow mosaic* is probably the most common virus disease of the black varieties. The foliage of diseased plants is distinctly yellow and the mottling on the leaves is rather diffused, seldom showing the dark green "blisters" of green mosaic. Both green and yellow mosaics are spread by the plant louse, *Amphorophora rubi.*

Symptoms of *streak* do not appear until the temperature becomes relatively high. There are two types of streak—mild, and severe; both affect only black raspberries. Affected plants are stunted, the degree of dwarfing depending on the length of time plants have been diseased. The leaflets are slightly or distinctly rolled, and this condition may be accompanied by a coarse splotching or obscure mottling; those at the tips of the canes are twisted or distorted by turns in the midrib. In severe streak, reddish or purplish stripes commonly are produced on the canes; in mild streak the stripes are steel- or gray-blue and narrower.

Control for the virus diseases in nursery and permanent plantings consists in roguing out and destroying all diseased plants, including all nearby diseased wild or cultivated plants. Inspection for virus diseases should start as soon as leaf growth develops. In roguing, the diseased plants may be pulled or dug, carried from the field, and burned. The plants should not be dug and allowed to wilt, because, as soon as the plants wilt, the aphids present crawl off and find their way to other plants, thus disseminating the virus of the disease. A more effective method than digging the live plants is to burn them in place with a torch. These torches are probably too expensive for use except in plantings grown for nursery stock. For new plantings it is of great importance that disease-free stock be obtained. Then, this healthy stock should be well isolated from disease sources.

Resistant varieties, providing their horticultural characteristics are good, should be given preference over susceptible ones.

"Running-out." When a raspberry planting becomes infected with mosaic the plants gradually decline in productivity and the planting is commonly described as having "run out." The following may be interpreted in the main as offering an explanation for "running out" of susceptible varieties.

"It is shown that production of carbohydrates is reduced by the presence of the virus and that its influence upon photosynthesis is evident. Naturally this leads to a decrease in the supply of reserves stored in the roots to be used in the succeeding crop of fruit and new canes. Progressive dwarfing of the canes produced each year in an infected planting bears out these observations. Fruit of poor quality and flavor is also attributable to a reduction in photosynthesis. In addition to a reduction in carbohydrate manufacture, it has also been possible to show that respiration is greatly increased. A high respiratory rate indicates that the products of photosynthesis are being used up much more rapidly in the mosaic-infected plants. The virus, perhaps, is wasteful of the stored energy of the diseased plant. This rapid release of energy together with the decrease in rate of formation of respirable material soon leads to starvation and eventually death. The scarcity of starch in diseased leaves is one incident, at least, of starvation conditions. Starch may be considered as one of the reserve forms of carbohydrate and in this case the simple materials are not converted into starch. If starch is formed it is soon hydrolyzed to produce respirable simple sugars when synthesis is slowed up or inactive. That something of this sort takes place is indicated by poor fruiting habits of mosaic-infected plants.

"Results of nitrogen analysis show that plants in which the virus is present do not contain so great a quantity of total nitrogen as healthy plants. In the ammonia fraction, however, the reverse is true. It is generally agreed that ammonia is normally used by plants in the formation of proteins, therefore an increase in ammonia in the diseased plants indicates that the virus has interfered with the processes of protein synthesis.

"Carbohydrate studies show lower percentage of carbohydrates in the diseased plants. This in connection with the accumulation of ammonia, indicates that the plants are unable to form proteins from the ammonia because of a lack of carbohydrates. Eventual starvation of the plant is the result of this failure of the synthetic processes and that starvation does occur is shown by the dwarfed growth made by infected shoots.

"The roots of diseased plants contain smaller quantities of all forms of storage material. This condition is probably due to the inability of these plants to synthesize materials and to the loss of material through excessive respiration of the plants in which the virus is present."[235]

Systemic Fungous Disease. One of the few systemic fungous diseases of the plants is *orange rust*. It is the chief disease of blackberries in northern

regions. Some varieties, as Eldorado (true to name), are more resistant to it than are others, such as Blowers and Mersereau. The leaves are small and distorted as they begin to unfold. Before they are full grown numerous, orange-colored, glistening bodies appear. This is followed in about two weeks by orange-colored blisters on the lower side of the leaf. In this stage there is usually a characteristic orange cast to the plant. The recovery which may seemingly take place relatively late in the season is only apparent, however, for all diseased plants will have rust the next year. Control is to destroy all rusted plants in the field and the surrounding territory before the spores are shed. The plants may be dug and allowed to wilt in the field, and need not be burned. As much of the root systems of infected plants should be removed as possible. Wild plants in the fence rows and waste land may be destroyed by placing a large handful of common salt around the crown of each plant.

Diseases Which Primarily Affect the Canes

Anthracnose (light-colored sunken spots surrounded by a red ring, chiefly on the canes) of black raspberries can be largely held in check by (a) removal of "handles" at early planting; (b) liquid lime-sulfur, 1–20, applied as a delayed dormant spray about the time the buds show green tips; (c) Bordeaux mixture applied when the blossom clusters can first be

Spraying black raspberry in the "delayed dormant stage" for control of anthracnose disease.

seen. Instead of lime-sulfur at the stage when the buds show green, good material to use is 1 per cent elgetol or paste dinitro (one can to 80 Canadian gallons of water or krenite one can to 100 gallons of water). Liquid lime-sulfur, 1–50, or the summer strength of dry lime-sulfur, may be used instead of Bordeaux mixture. The second application may cause some burning of the foliage during some years. The disease is usually worse when rains are plentiful. The disease saps the strength from the canes; infected berries develop poorly, dry up, and turn brown. Anthracnose spots on red raspberry canes are usually very small. When cane infections on this host are numerous, the fungus grows extensively throughout the bark producing the so-called "gray-bark" phase in autumn. Individual drupelets of the red raspberry fruit may become infected, giving the fruit a one-sided or deformed appearance.

There is no satisfactory control for *crown gall* (swellings on the roots, less frequently on the crowns and canes). Good cultural methods and application of suitable fertilizer do much to enable the plants to tolerate the effects of the disease. New plantings should be started with plants as free as possible from gall and set on non-infected soil. It is helpful to use crops such as corn, oats, or wheat preceding raspberries. Suckers from young plants are comparatively free from gall.

Weakening of the plant by winter freezing is commonly a forerunner of *cane blight* (smoky-colored, cankered areas on the canes in which the wood and bark are dying or dead). Good culture, including adequate spacing in and between rows, and removal of the second-year canes soon after harvest, largely takes care of the trouble. The control for *Gloeosporium blight* (wilting of tips and turning blue of the canes) is the same as for anthracnose.

The control for *spur blight* (dark reddish discolorations in the bark at the base of the leaf petioles and death of the leaf and axillary buds) is to provide conditions for free circulation of air around the canes, as by thinning of canes, good spacing of rows, or other procedures that avoid too dense growth. Good drainage is significant, as is control of weeds. Spray (a) to eradicate—with liquid lime-sulfur 1-10 in the dormant season, or with 1 per cent elgetol (paste dinitro) when the buds show green tips, (b) to protect—with Bordeaux 6-8-100 when the suckers are 8–10 inches high and again two weeks later.

Verticillium wilt has been mentioned under Previous Crops. It has been

a leading factor in causing certain districts in Western Oregon to discontinue the growing of black raspberries.

Diseases Which Primarily Affect the Leaves

Mildew seriously affects red raspberries, especially the Latham, in some regions. In nursery stock, the disease can be controlled by pruning back dormant plants to ground level the year before digging. Use of Bordeaux mixture or sulfur sprays or dusts is not very helpful. In fact, without direct control measures the infection may be severe one year and absent the next. *Leaf spot* is seldom a serious problem on raspberries, but where it is troublesome the best control procedure is probably about the same as for anthracnose. The Viking variety is very susceptible to *late yellow rust* which sometimes causes a premature loss of leaves. The infected leaves are covered with orange-colored masses of fungus spores which later turn brown and may drop. The orange-colored spores may also be produced in the fruit. Raspberries should not be planted in the vicinity of spruce trees where these are an alternative host for the disease. The site for the planting should have good air circulation.

Miscellaneous Disease

Rosette or "double blossom" is common on blackberries and dewberries in the South. The young buds become infected by the fungus when forming early in the season. These are the buds which should produce the crop for the next year. The fungus grows down into the bud and remains dormant over winter. The diseased buds may be detected early in the spring as they are slightly more swollen than normal buds and frequently are reddish. Small buds may be formed laterally to the main buds. The sepals and petals are increased in size and number and the petals are more or less wrinkled. Fruit either does not mature or is small and worthless. The irritation set up by the fungus may also result in a small bushy growth known as "witches broom" instead of the normal spur growth. This also occurs at the renewed growth the spring following infection. Control is to hand-pick the infected blossoms before they open in the spring. It is advisable to remove and burn infected vines where the disease has not become widespread in a planting, to prevent its further spread. Diseased wild blackberries and dewberries should be cut out in nearby woods and fence rows and burned.

Insects Affecting Fruit and Foliage

The *raspberry byturus* causes wormy berries. Such berries are always objectionable; canners may refuse fruit when occasional infested berries are detected, because of Pure Food Law restrictions. When mature, the larvae of this pest are 7–8 mm. long with light brown areas on each segment. They feed chiefly on the core of the berry and some remain in the picked fruit. Because the receptacle or core is a part of the harvested fruit, where both are grown, Logan berries are more seriously affected than are raspberries. This fruit worm has been responsible for heavy losses, in certain severe cases causing discontinuance of Logan culture. The adult yellowish brown beetles feed on the fruit buds and unfolded leaves. They feed also on the stamens, pistils, and around the base of the stamens of open flowers. Some injured blossoms show only a brownish discoloration, but buds and blossoms may be completely destroyed. Distorted berries may form from the injured blossoms, and in other cases the larval injury in the fruit causes some of the so-called "crumbly" raspberries. Insecticides are applied to control the beetles before they lay their eggs. Dusting three times with derris gives good control: 10 days after blossoms appear; 10 days later; 10 days still later.

The larvae of the *raspberry sawfly* feed on the under surfaces of the leaves. As the feeding continues between the veins the leaves become skeletonized. Before the earliest blossoms open, spray with lead arsenate two pounds, hydrated lime eight pounds, in 100 gallons water. If necessary to treat after bloom, a derris (rotenone) or pyrethrum spray or dust is used.

The work of the *blackberry leaf miner* is characterized by large brown blisters or mines with a flattened, active larva, less than $\frac{1}{3}$ inch long, feeding within. There are two broods each year, the first about June 1 and the second in August. The insect may be controlled, to some extent, by spraying with two pints nicotine sulfate and four pounds of soap to 100 gallons water.

Red spider injury is caused by the young and mature mites feeding, for the most part, on the underside of the foliage. The combined rasping and sucking manner of attack not only mechanically disturbs the leaf tissues but results in sap losses which at first cause the foliage to appear covered with minute yellow spots. Later the leaf surface presents a grayish, lustreless aspect, and still later, if the injury is severe, the entire leaf may become

brown and dead. Hot, dry weather favors the pest. A good rain helps naturally to overcome an infestation. Spraying with eight gallons of stock flour solution (one pound flour to one gallon of water) to 100 gallons of water is somewhat helpful. Another somewhat useful control where the pest is commonly troublesome is to spray annually in the spring with a 1 per cent summer oil emulsion and $2\frac{1}{2}$ pounds soap to 100 gallons, directing the spray to the underside of the leaves. This spray should not be applied to severely injured plants or in very hot weather.

The *blackberry mite* is a microscopic mite which feeds between the drupelets and core of the berry, causing the "redberry disease of blackberries." Affected berries are brighter red than the unripened fruit, become hard, and remain on the bushes until the old canes die in winter. The "redberry" condition may vary from a single red drupelet in a black berry to a single black drupelet in a red berry. This mite is a major pest on trailing varieties in some districts and requires the annual application of one or two sprays for its control: e.g., in Washington,[238] lime-sulfur, one gallon to $12\frac{1}{2}$ gallons water, is applied in March, and again, 1–40, in early May. A substitute for the second spray is five pounds wettable sulfur to 100 gallons of water.

Aphids are serious insect pests of raspberries. The injury, however, is caused indirectly in that they spread the virus diseases. Control by spraying or dusting is not feasible, because of the frequency of migration from outside sources.

Insects Affecting Stems and Roots

These are largely controlled by the practices normally followed in bramble-fruit culture. Removal of canes which have fruited helps in the control of the insects in this group. A little extra watchfulness while pruning will enable the workmen to detect infested canes, the removal of which will reduce still further possible injury from this source. Cultivation of the planting and cleaning up of neglected nearby areas supporting vegetation suitable for harboring the pests help in the control of the insects.

One insect that these measures will help control is the *snowy tree cricket*. In late summer or early fall the curved, light-orange-colored eggs are deposited in closely spaced, single rows about two inches in length. The insect feeds on the tender young leaves and tips of canes but the chief injury is due to the egg punctures which weaken the cane so that it may

break. Helpful control is to spray badly infested plantings with lead arsenate 2½ pounds, hydrated lime 10 pounds, in 100 gallons water before the earliest blossoms open and again after harvest.

The *raspberry cane borer* makes two rows of punctures encircling the stem about six inches below the growing tip. The two rings are located about an inch apart, and it is in this short section that the egg is laid. The tip above the puncture wilts and droops. Cutting off the wilted tips two inches below the lower ring soon after infestation appears helps check the trouble. The *cane maggot* attacks the young canes, commonly when they are 1–3 feet long. The symptoms are a sudden wilting of the young shoot with a purple discoloration appearing at the point where the maggot is girdling the cane. A control is to remove and burn wilted canes as soon as observed in spring. The injury characteristic of the *red-necked cane borer* is swellings in the canes. In extreme cases the canes may die, but usually the damage shows in failure to fruit and in breakage of the canes. Removal of the old canes by pruning and eliminating and burning canes showing swellings checks this pest. Badly infested plantings can be sprayed as suggested for the snowy tree cricket.

Plants affected by the *raspberry root borer* are not vigorous, a portion showing a stunted, weakened appearance. Lateral growth starting in the spring may be followed by a sudden wilting and death of the entire cane. In removing infested canes or in thinning new canes, the cuts should be made as close to the crown as possible. Conspicuous, white, circular objects about ⅛-inch diameter, occurring at the base and extending well up on the canes, indicate infestation by *rose scale*. The feeding insects weaken the plants, but rarely is the infestation sufficiently severe to cause significant damage. A dormant spray of standard strength will control this pest.

4. Currant and Gooseberry Culture

THE INDUSTRY AND REGIONS

THE TOTAL value of the currant and gooseberry crops in the United States is slightly more than $300,000 a year, and is based upon about 4,000,000 quarts from 4,000 acres.

Almost half the currant acreage in the United States is in New York State. A total of about 1,000 acres of currants is grown in Ulster and Orange counties in the southeastern part of the state; more currants are grown commercially in Ulster County than anywhere else in the United States. Berrien County, Michigan, probably ranks next. Some of the chief areas are: Monroe County, south of Lake Ontario in northern New York; Chautauqua County in western New York; Erie County, Pennsylvania; near Cleveland in Cuyahoga County, Ohio; Allegan County, Michigan; Minneapolis and St. Paul in Hennepin County, Minnesota; Douglas County in southwestern Missouri; Jefferson County, Colorado; near Seattle in King County, Washington; near San Francisco in Alameda County, California.

In only one county in the United States are there more than 100 commercial acres of gooseberries, namely, Marion County, Oregon. Other important areas are: Polk and Linn Counties in Oregon; Oceana and Berrien Counties in Michigan; King and Whatcom Counties in Washington; Alameda County in California; and Larimer County in Colorado.

Some of the main conditions which limit the production of currants and gooseberries in the United States are:[165] (a) The heat of summer. (b) Drought. (c) Where the white pine is a commercially important forest tree, increased attack of the white pine blister rust may result as part of the life cycle of this disease is passed on it. Quarantine regulations also govern

the interstate movements of plants of these fruits. (d) The currant maggot in certain regions. (e) The market for currants and gooseberries is practically limited commercially to the fruit products manufacturers. For the home garden or local market the ease of culture, the small amount of space required, and the numerous uses to which these fruits can be put in the making of culinary products commends them to consideration.

About 50 per cent of Canada's production of currants and gooseberries is in Ontario, 25 per cent in British Columbia, 12½ per cent in Quebec, and 5 per cent in Nova Scotia. In Ontario, the leading area devoted to these crops is along the north and south shores of the western end of Lake Ontario, chiefly in Wentworth, Lincoln, York, Peel, and Halton counties. The probable distribution of quantities of currants and gooseberries in

A hybrid black currant which combines the resistance to rust of the Siberian currant with the good fruit characteristics of the commercial and garden varieties. (Courtesy, M. B. Davis, Dominion Horticulturist, Central Experimental Farm, Ottawa, Ontario.)

Canada would be about 50 per cent for black currants, and 25 per cent each for red currants and gooseberries.

DEVELOPMENT OF VARIETIES*

Red Dutch and White Dutch were sent from England to settlers in America in 1629. Cherry currant was brought to the United States about 1840. Though Cherry is still catalogued, it is doubtful whether it can be obtained true-to-name from any nursery. Cherry, Fay, and Versailles have been badly confused.[179] Prince Albert was introduced about 1850, Victoria a few years earlier, and London Market in 1879. Fay, which appeared in 1880, became the first widely grown variety originating in the United States. Within the next 20 years the following varieties which originated in this country appeared: Chautauqua, Perfection, Filler, Pomona, Red Cross, and Wilder.

The history of white currants in America also dates to 1629. The white currant attained little popularity in this country, and few varieties originated here. White Dutch, White Grape, and White Transparent were introduced from Europe.

The black currant (*Ribes nigrum*), though probably introduced as early as the red and white, found little favor in the United States. It is, as previously mentioned, popular in Canada.

Some variety representatives of currant and gooseberry species are as follows:[45]

Red and white currants (*Ribes*).

R. sativum (red): Chautauqua, Diploma, Wilder.

R. sativum var. *macrocarpon:* Cherry, Fay's Prolific.

R. houghtonianum (*R. rubrum x sativum* or *R. sativum x rubrum*):

Red: Perfection, Red Dutch.

White: White Dutch, White Grape, White Imperial, White Transparent.

R. rubrum (red): London Market, Victoria.

R. pallidum (*R. petraeum x rubrum*) (red): Prince Albert.

R. nigrum: The cultivated black varieties.

Gooseberries (*Grossularia*).

G. reclinata: European varieties.

G. hirtella: erroneously *G. oxycanthoides:* Pale Red (also known under the names Cluster, American Cluster, and Ohio Prolific).

* The origin of additional varieties is given under Characteristics.

G. rustica (*G. reclinata uva-crispa x hirtella*): Downing, Carrie (almost pure *G. hirtella*), Pearl, Poorman, Red Jacket, Van Fleet.

G. utilis (*G. cynasbati x reclinata*): Mountain.

G. van-Fleetiana (*G. missouriensis x reclinata*): Glenndale.

Though many botanists unite currants and gooseberries in the genus *Ribes*, others have preferred to keep them separate and have restored the genus *Grossularia* for the gooseberries.[247]

Until the Houghton appeared, attempts to grow gooseberry varieties in America were restricted to European sorts. Houghton, which originated from seed sown in 1833 by Abel Houghton, Lynn, Mass., was the first domestic variety of note. Downing, a seedling of Houghton, originated about 1885. The wide adaptability of Downing and Houghton, the ease of propagation (particularly of Houghton), and comparative freedom from mildew have enabled them to persist for extensive culture in spite of only fair qualities of fruit. Greater consideration should be given to a number of varieties discussed under Characteristics.

GROUPING* OF RED CURRANTS, PARTIAL[479]

(A) Blossoms saucer-shaped, uncolored except for a central disk which is sometimes red. Foliage drops in late summer or early fall.

(B) Thick, coarsely veined leaves

Cherry, Chautauqua, Fay

(BB) Leaves not markedly thick or coarse

(C) Leaves folded or cupped

Red Dutch, Diploma, Pomona

(CC) Leaves flat or nearly so

Red Cross, Wilder

(AA) Blossoms saucer-shaped, sepals blotched with red. Leaves markedly pubescent beneath. Foliage hangs late. Bushes of good size.

(B) Foliage a gray-green

Victoria

* For further groupings see Thompson, C. R. The identification of red currant varieties. Long Ashton Ann. Rpt. for 1931. 28–29. 1932. Amos, J. Red currant varieties. East Malling Res. Sta. Ann. Rpt. 1928. Bunyard, E. A. A revision of red currants. Jour. Pom. Vol. 2. 1920–21.

(BB) Foliage a very light green, margin of the leaf lighter in color, giving the leaf an appearance of a narrow edging of white.

London Market

(AAA) Blossoms campanulate, sepals splashed with red. Bush very vigorous, with stout, stiff branches. New shoots bright red during early summer. Foliage dark green, almost black, hanging on the bushes until winter.

(B) Leaves appear before blossoms. At first, foliage is yellowish but soon turns a dark green with a decided gloss. Fruit late, light red

Long Bunch Holland

(BB) Blossoms precede leaves. Leaves narrow, three-lobed, smooth but not glossy. Fruit light red, very late.

Prince Albert

CHARACTERISTICS OF VARIETIES

Leading Red Currant Varieties

Albert (Prince Albert, Rivers Late Red). Ripens very late, which is probably its chief merit. Origin—imported from France, about 1850.

Cascade. Ripens about a week earlier than Red Lake and the berries are larger but the clusters are not so long. Origin—University of Minnesota; open-pollinated seedling of Diploma.

Cherry. Unproductive when true to name. The Cherry offered in the trade is usually some other variety.

Diploma. Spreading habit. Not so productive in field plantings as are some other varieties. Origin—Cherry x White Grape, by Jacob Moore, Brighton, N. Y., in 1884.

Fay. Clusters and fruit large, stems fairly long, hence easy picking. Losing in popularity because of early bloom making it subject to frost damage, the canes sprawl and are frequently broken, its comparatively high acidity of fruit, and the higher yield of other sorts. Origin—with Lincoln Fay, Portland, N. Y., about 1868; Victoria x Cherry.

Filler. Planted chiefly in the Hudson Valley, N. Y. More productive than Fay, which it resembles in fruit. Origin—with a Mr. Filler, Milton, N. Y., about 1892.

London Market. Planted chiefly in southern Michigan and in Indiana. A late midseason variety. The combination of short stems and leafy spurs makes clean picking difficult in Ohio experience. Origin—England, imported by Harry Bowles, Bravo, Mich., in 1879.

Long Bunch Holland (Franco-German). Late. Resistant to heat and drought

but otherwise only a fair variety. Origin—France; imported about 1855 by Samuel Edwards, Lamoille, Ill.

PERFECTION. Fruit large. Capricious as to its site. Under suitable conditions it is an outstanding variety. Not so vigorous as many others, throws comparatively few canes from below soil level, and scalds easily on the bushes. The fruit is borne on older wood than is usual for red currants. Origin—with C. G. Hooker, Rochester, N. Y.; Fay x White Grape.

RED CROSS. High quality but not so good for jelly as some other varieties. Sometimes becomes badly defoliated before or during the picking season. Fruit subject to cracking. Origin—with Jacob Moore, Brighton, N. Y.; Cherry x White Grape, first fruited in 1889.

RED LAKE. Fruit large, in fairly large clusters with long stems, good quality, rather lighter in color than some of the older varieties such as Fay. Ripens midseason to late. Vigorous, hardy, and productive. Origin—Minnesota State Fruit Breeding Farm, about 1920; parentage unknown.

STEPHENS NO. 9. Fruit large, good quality, less acid than some. Clusters medium to large with fairly long stems. Moderate vigor, inclined to be sprawly in habit. Origin—with C. L. Stephens, Orillia, Ont.

VICTORIA (Raby Castle). A late, hardy variety, but ranking only fair in comparison with other varieties. European origin.

WILDER. Probably the leading commercial variety over a wide range of conditions, even though excelled in a number of characteristics by certain other varieties. A vigorous, productive variety. Origin—with E. Y. Irvington, Ind., about 1876. Named in honor of Marshall P. Wilder, a President of the American Pomological Society.

LEADING WHITE CURRANT VARIETIES

WHITE GRAPE. The leading white currant, but this fruit is of little commercial value. European origin.

LEADING BLACK CURRANT VARIETIES

BOSKOOP GIANT. Fruit large, good quality, ripens early. Production variable (see Pollination). Origin—England.

CHAMPION. Less vigorous than Naples. Later than Naples. Productive. Fruit ripens unevenly. Clusters short. Origin—England.

CLIMAX. Berries medium to large. Heavy yielder. Origin—with Wm. Saunders, London, Ont.; seedling of a Black Naples seedling, before 1889.

KERRY. Vigorous and productive. Clusters large, fruit large, ripens evenly. Midseason to late. Origin—with Wm. Saunders, London, Ont., before 1887.

LEE. Vigorous, productive; short, thick clusters. Origin—England.

MAGNUS. Its evenness of ripening makes it possible to harvest the entire crop at one picking. Origin—with Wm. Saunders, London, Ont.; seedling of a Black Naples seedling, before 1889.

NAPLES. Strong, vigorous grower. Prolific. Buds borne on short clusters and well distributed over the bush. Clusters and fruit variable in size. Origin—England.

SAUNDERS. Vigorous and productive. Origin—with Wm. Saunders, London, Ont., before 1887.

VICTORIA. Ripens unevenly, mostly between Champion and Naples. One of the most vigorous varieties, but capricious as to site. Origin - England.

LEADING GOOSEBERRY VARIETIES

CARRIE. A hardy, productive variety with small fruit which is red when ripe. Origin - with Wyman Elliott, Minneapolis, Minn.; Houghton x Industry in 1893.

CHAUTAUQUA (Columbus, Portage, and Triumph are similar). The fruit of European varieties is larger than that of American sorts but is more subject to mildew and other adversities. When grown successfully, the much larger fruits make European varieties highly preferable. The fruit of Chautauqua and the three similar varieties is pale green.

CLARK. Fruit very large. Moderately vigorous, productive, fruit easy to pick. Generally free from mildew. Hardy and outstanding in Ontario, except in the colder parts. Propagated by layering. Ripens late midseason. Origin - with M. C. Smith, Burlington, Ont., a natural hybrid of European and American varieties.

COMO. Green fruit. Productive. Origin—Minnesota Fruit Breeding Farm; Pearl x Columbus.

DOWNING. Probably the most widely planted gooseberry in the United States and Canada. Thrifty, vigorous, and productive; easy to propagate. Fruit pale green; small; comparatively smooth. Origin—with Chas. Downing, Newburgh, N. Y., as a seedling of Houghton in 1855.

FREDONIA. Plants vigorous and of open habit, which makes for easy picking. Fruit large, of good quality, matures late, and is dark red when fully ripe. Origin - New York Agr. Exp. Sta.

GLENNDALE. Introduced by the U.S. Dept. of Agriculture[179] because of its adaptation to the southern limit of gooseberry growing where other sorts die out or are grown with difficulty.

JOSSELYN (Red Jacket). Fruit reddish green; medium size; productive. Origin—with Wm. Saunders, London, Ont.; supposedly from Houghton x Red Warrington, about 1876.

OREGON (Oregon Champion). Fruit green, medium size. Ripens late. Highly productive. A leading sort in Pacific Coast States. Origin -with Dr. P. Pettyman, in Oregon; Crown Bob x Houghton.

PEARL. Much like Downing in fruit but sometimes slightly larger. Origin—with Wm. Saunders, London, Ont., Downing x Red Warrington.

PIXWELL. Plants with few thorns. Canes rather slender and somewhat drooping on older plants. Very hardy and productive. Berries oval, about twice as large as Carrie, pink when ripe. It is the abundance of fruit which hangs away from the stems making it easy to pick, that gives it its name Pixwell. Origin - *Ribes warscewiczii* x Oregon Champion; named and distributed in 1952 by the North Dakota Exp. Sta.

POORMAN. Red. One of the largest fruited American sorts. Quality almost good enough to be eaten out of hand as a dessert fruit. Makes a very vigorous, healthy bush but does not bear as young as other sorts. Thorns less objectionable than in most sorts. Origin - with W. H. Craighead, Brigham City, Utah, Houghton x Downing.

SILVIA. Red. Hardy and productive. High quality when ripe. Probably superior to Pearl. Origin - with Wm. Saunders, London, Ont., parentage unknown.

WHITESMITH. Fruit green, large, good quality, ripens early. Subject to mildew. Origin—England.

DURATION AND YIELD OF CURRANT AND GOOSEBERRY PLANTINGS

The length of life of a currant or gooseberry planting depends much on the care it receives. At least 10–12 crops may be expected from reasonably well cared for plantings. Crops have been produced from some bushes until 20 years or more old. The plants should be kept thrifty by liberal fertilizing, proper pruning, and control of insects and diseases. When waning vigor is detected in commercial fields the advantages of young, vigorous plants may more than repay the cost of replanting. The period of productiveness is longer in northern regions than towards the southern limits.

Good yields per acre of currant or gooseberry fields, plants 4 × 8 feet, are about 3,200–4,800 quarts for red currants and a little less for black currants, and 4,000–6,400 quarts for gooseberries. Yields of these fruits, under exceptionally favorable conditions, are sometimes as high as 10,000 quarts per acre. Under garden cultivation, yields per large bush frequently are from five up to as high as 10 quarts for these fruits.

PROPAGATION

HARDWOOD CUTTINGS

Currants are usually propagated by hardwood cuttings, which are taken after the plants become dormant and the wood is well matured. The cuttings are made from the new wood. Canes of medium size are preferable to very large or to spindly ones.

Currant cuttings are usually made about eight inches long, though in the Pacific Northwest a length of 10–12 inches is preferred. The position of the lower cut on the cuttings is of little consequence. When gooseberries are propagated by cuttings, the procedure is much the same as with currants.

The handling of the cuttings as outlined for grapes also applies to currants and gooseberries.

American-type gooseberries vary in the capacity for successful propagation by cuttings. The widely grown Downing reproduces only fairly freely from cuttings. Houghton, Poorman, and Van Fleet, on the other hand, root readily from cuttings.

Layering

Simple layering. If only a few plants are needed, several branches, while attached to the plant, are bent down and partly covered with earth. They are held in place by the weight of the earth or by hooked pegs forced into the ground. This layering may be done in the fall or spring and by the next fall the layers should be rooted sufficiently to be set out in a nursery row. Slow rooting varieties may need another year before they are rooted well enough to be moved.

Mound layering. This method is used for quantity production of gooseberry plants. The first step is to cut the branches back severely in the dormant season, and so encourage the formation of numerous vigorous shoots. In midsummer, earth is mounded halfway up the shoots. The shoots of American varieties usually root by autumn. If root development is good the shoots are cut off the parent plant and set in nursery rows where they are grown, usually for 1–2 years. If root development is poor under the mounds (as commonly occurs with European varieties), those shoots should be left attached to the parent plant for another year.

LOCATION AND SITE

Soil

The soil requirements are little different from those of the fruits discussed previously. Light sands are none too desirable, largely because of the heat factor. Currants will thrive on soil slightly too wet for most other small fruits (except the blueberry and cranberry), but neither currants nor gooseberries will do well on soil where water stands for any length of time.

Exposure

In selecting a site, the same considerations apply as were discussed for the other fruits. Since gooseberries are more subject than currants to mildew, a relatively higher site providing better air circulation is desirable for the former, but neither should be in low pockets.

A reduction in the intensity of sunlight by providing some shade, which at the same time results in a cooler atmosphere, helps control mildew and avoids excessive sunscalding of gooseberries. The shade should not be so low and dense as to increase mildew by preventing good air circulation. A northern exposure is best. Gooseberries and currants bloom

earlier than the other small fruits, but their hardiness is indicated by their northern distribution.

Interplanting Currants and Gooseberries in Orchards

Currants and gooseberries are sometimes used as intercrops in intensive orchard culture. The plants may be set in the orchard either between the tree rows or in the tree rows. The shade provided by the trees is of some benefit, particularly for the gooseberry, the fruit being protected from sunscald, and, to a certain extent, distribution being extended southward. One of the main faults with interplanting is the crowding of too many bushes between the orchard trees. This results in a deficiency of moisture and fertility for both trees and bushes and also causes much inconvenience in orchard operations. Where trees are set only 20 feet apart there is room for only one bush of cane fruits between each pair of trees and it is questionable whether there is enough space between tree rows for a row of cane fruits. At greater distances, say 24 feet, there would be sufficient room for two bushes between each pair of trees and also for a full row of currants or gooseberries between rows of trees. At still greater distances, more of the cane fruits can be set both in and between rows.

Attempts to make currants or gooseberries a permanent part of a vineyard are usually unsuccessful; also, the yield of the grapes is likely to be decreased.

PLANTING

The procedure in preparation of the soil is the same as for the other fruits discussed.

Time of Planting

Currant and gooseberry bushes start growth very early in the spring; therefore, fall planting merits attention, especially if the plants would otherwise be set in late spring. Currants and gooseberries lose their leaves comparatively early in the fall. Therefore, the bushes may often be planted by late September (as soon as dormant), thus providing the roots ample time to become established before winter. Gooseberries sometimes are not ready for fall planting until several weeks later than currants. If the ground is very dry in the fall it may be better to delay planting until spring. Spring planting is generally satisfactory, providing it is done early. Late spring planting may seriously affect the year's growth.

Choice of Plants

Vigorous, well-rooted, one-year-old currant or gooseberry bushes are best for planting. Two-year plants usually cost more. There is likewise danger that these two-year plants sometimes may be the cull stock left at the end of the first year after the best one-year stock has been sold. On the other hand, weak one-year plants may be less satisfactory than good two-year-olds. A vigorous, well-rooted, one-year plant is likely to be more easily set, suffer less in transplanting, and make more progress toward producing a crop in the permanent planting than it would during the same time in the nursery row.

Planting Distance

Common spacing for red currants and gooseberries is 4–5 × 7–9 feet. Black currant plants, which grow larger than those of red currants, are set about a foot farther apart, in the rows. A wide space between rows facilitates cultivation and spraying. In dry seasons, especially, a closely spaced planting will suffer more than where the rows are farther apart. Certain varieties are more vigorous and more sprawly than others and so are spaced a little farther apart. American gooseberries or those partly of American ancestry usually make larger bushes than do the European.

Spraying is as necessary with these fruits as with tree fruits and most growers now use large spray outfits that require adequate space between rows or groups of rows. The bushes may be set out in a long but narrow planting so that all rows can be reached from the outside. A modification of this plan, suitable for a large planting, is to leave an occasional wide space, perhaps every 5–6 rows.

If larger implements than the single-horse cultivator are to be used for tillage wider spacing will be needed between every row. Not only team cultivators and discs are being used, but also the tractor disc. This, of course, makes for much greater speed in cultivation but it is doubtful if such a heavy deep-cutting implement as a tractor disc should be used with shallow-rooted plants like currants and gooseberries.

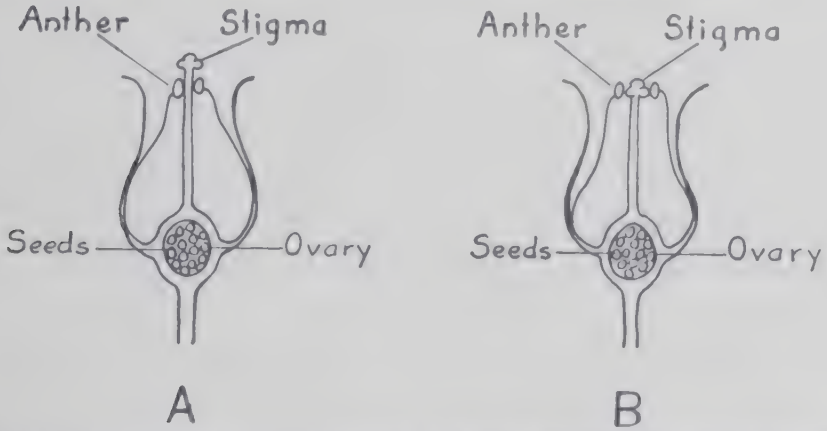
Just how far to space the rows must be decided by the individual grower but 8–10 feet is suggested in Ontario,[361] and, in the rows, red currants five feet, gooseberries five feet, and black currants 6–7 feet apart. This spacing, which is more than recommended in the past, results in greater feeding area and greater water supply per bush and results in more

vigorous growth and greater yield per bush. However, to obtain the greatest yield per acre, it is necessary to arrive at a reasonable balance between the number of bushes or spacing and yield per bush. The spacing can be overdone, and so result in reduced per acre yield.

Pollination

Most currants and gooseberries are self-fruitful, and so there is no need of interplanting varieties for cross-pollination. Furthermore, gooseberry varieties can bear fruit without help of insects for cross-pollination.[112]

Several groups of black currant varieties, however, and particularly that group represented by Boskoop Giant, have a flower structure which prevents self-pollination of the flowers. The first few flowers at the base of a cluster usually hold their stigmas level with the anthers or slightly above or below and this situation prevails to the tip of the cluster in most varieties. But in Boskoop Giant, many of the flowers, especially those toward the tip end of the cluster, hold their stigmas out beyond the anthers in varying degree. This difference in stigma position in relation to the anthers affects the amount of fruit set. If the weather at the time of bloom is favorable to insect activity so that pollination is effectively achieved, then a good set of fruit on Boskoop Giant and similar varieties may be expected; but if the weather and therefore conditions for pollination are



In the black currant there are differences in flower structure which affect pollination and therefore yield. (A) Since the stigma protrudes beyond the pollen-bearing anthers it is not easily self-pollinated and yield is adversely affected. (B) The stigma and the anthers are on the same level, thus facilitating pollination and therefore fruit-setting. (Courtesy, Hort. Exp. Sta., Vineland, Ontario.)

not favorable, then only a few easily self-pollinated flowers at the base of the clusters will set fruit.

Setting the Plants

Currant and gooseberry bushes are usually planted by the spade or furrow method, slightly deeper than they grew previously. The soil should be tramped firmly after setting each plant. Pruning off damaged root portions may be done. Heading back the top at planting may or may not be necessary according to conditions.

TILLAGE AND MULCHING

Currants and gooseberries require a plentiful supply of moisture and a cool soil. Cultural practices should be directed above all to controlling weeds. Frequent and shallow cultivation should be practiced during the life of the planting. The roots are usually close to the surface. Cultivation can be done more deeply the first year than in later years. At the first working, the disc must usually be used, but later the springtooth harrow is likely to be better as it is less destructive of the roots. The grape hoe is of value in reducing the amount of hand labor near the plants.

In some plantings, mulching is substituted for cultivation. The mulch keeps the soil moist and cool, and smothers weeds, but to be properly effective it must be maintained from year to year. Mice or fire sometimes seriously damage mulched plants. Straw mulch alone, as shown later, is not entirely satisfactory, and nitrogen fertilizer should be used with it. In an outstanding gooseberry planting in Ontario, the grower has used quite heavy and frequent applications of alfalfa screenings and covered the ground around the bushes to a depth of five or six inches. The increase in size of bush, size of fruit, and total crop, have been very marked and very much worthwhile in spite of the high cost of material.

Fruit-bud Formation

The flowers of the red currant differentiate in late July or early August in New York.[313] The growing points of the gooseberry differentiate into flowers about the first week of August.

FERTILIZER

Currants and gooseberries are heavy feeders. They require plenty of humus in the soil, and so the turning under of manure and cover crops is helpful.

In Ohio,[414] both manure and nitrogen fertilizer increased the yield of the Wilder red currant, Table 39. Mulching with straw without the addition of nitrogen resulted in yellowish foliage. When the nitrogen was added to the straw, the foliage became dark green, and both yield and growth were increased. Responses from phosphorus, potash, and lime proved less beneficial than from nitrogen on this soil. Currants have benefited from potash applications in Massachusetts. Potash may be useful on gooseberries. In England,[500] a deficiency in potash has been clearly evident in the composition of the ash of the leaves and stems and less so in the berries. (See also under Bramble Fruits with respect to the role of a mulch in increasing the availability of potassium.)

Table 39

COMPARISON WITH ADJACENT CHECKS OF ANNUAL FERTILIZER TREATMENTS ON WILDER CURRANT. PLANTED 1926, EIGHT PLANTS PER PLOT. OHIO[414]

Plot	*Row*	*Treatment*	*Yield (quarts)*						
			1928	*1929*	*1930*	*1931*	*1932*	*1933*	*1934*
A	1	No fertilizer	4.0	6.0	18.0	26.2	36.0	34.0	46.0
	2	Manure (20 tons per acre)	8.8	11.0	16.0	39.0	48.0	45.0	48.5
A	5	No fertilizer	11.0	12.0	26.0	33.0	46.0	50.0	47.6
	4	Sulfate of ammonia (spring 160 lb.)	7.9	16.0	35.0	38.5	42.0	45.0	52.0
B	5	No fertilizer	5.8	13.0	21.5	27.0	46.0	58.0	51.5
	4	Sulfate of ammonia (80 lb. spring, and 80 lb. Sept. 1)	13.8	15.0	32.0	38.0	49.0	45.0	53.5
B	5	No fertilizer	5.8	13.0	21.5	27.0	46.0	58.0	51.5
	6	Manure (10 tons plus superphosphate, 300 lb.)	7.8	11.0	22.5	32.0	66.0	66.0	63.0
C	1	No fertilizer	5.2	6.0	7.3	17.0	36.0	50.3	44.0
	2	Straw (2–5 tons plus nitrate of soda, 200 lb.)	12.8	15.0	16.0	37.5	63.0	50.5	49.5
D	1	No fertilizer	4.3	7.0	11.0	24.0	67.0	43.0	42.5
	2	Straw (2–5 tons)	5.0	6.0	8.0	20.0	42.0	48.0	43.5

PRUNING CURRANTS AND GOOSEBERRIES

Red and white currants fruit at the base of one-year wood and more so on spurs on two- and three-year old wood. Older wood produces inferior fruit. The object in pruning is to remove wood older than three years and to let it be replaced by a suitable number of younger growths. It is largely a thinning and renewal process. The average well-pruned dormant bush

when three years old may consist of about three shoots each of three-, two-, and one-year-old wood. At this age, a few more of each kind of shoots may be suitable but, if overdone, may produce undesirable conditions in later years. With older bushes, a few more canes of the various ages are usually left.

The black currant bears the most and best of its fruit on wood of the previous year's growth; therefore, pruning is largely directed to leaving a plentiful supply of young wood. Where borers are troublesome in black

A mature currant bush after moderate pruning.

currants it is particularly important that all wood older than two years be removed; also any canes that do not appear to be thrifty should be cut out.

The pruning of currants or gooseberries, which is done in the dormant season, consists mostly in thinning out the canes. Heading back of the canes is necessary or advisable only with high or straggly, spreading bushes. In red currants the young vigorous shoots that are to take the place of the older canes may be shortened to prevent the bush from becoming straggly and to space the development of fruit spurs evenly along their whole length instead of mostly at the ends. In black currants this shortening of the branches is not advisable.

With all types, weak growth and branches lying close to the ground should be removed. Training gooseberries to a tree form finds little favor in this country.

HARVESTING AND MARKETING CURRANTS AND GOOSEBERRIES

So many different kinds of containers are used in the harvesting and marketing of currants and gooseberries that it is difficult to select any outstanding one. Often, customers take their own pails and baskets of various kinds to the planting and place the fruit in them. For commercial products the fruit may be hauled a reasonable distance in bushel baskets. In retail trade, sales are usually made on a quart basis; preserving companies usually pay on a pound basis, the containers being returned.

The picking period usually is long, sometimes a month or more. If, however, the fruit is sold for jelly making or preserving, it is usually desirable to pick most of the crop in a few pickings.

Red currants are best picked by separating the stem of the cluster from the bushes with the fingers. Grasping the clusters of berries and pulling them off is undesirable. Picking for jelly-making purposes should be done when the fruit is slightly underripe, especially with the milder flavored varieties such as Perfection. Avoid the presence of leaves with the fruit in the container. Harvested fruit should not stand in the sun.

The usual method of picking gooseberries is to strip the fruit from the plants by hand. The thorny nature of the bushes makes picking disagreeable. Pickers often wear gloves for protection. In some of the larger plantings a scoop is used. For the general market, gooseberries should be picked more carefully than by the stripping method in which some of the fruit is cut by the thorns and spoils quickly. Leaves should be separated from the fruit; with large quantities of fruit a grain fanning mill is helpful in cleaning out the leaves. Since gooseberries sunscald quickly after picking, the filled containers must not stand in the sun.

Probably the green-colored gooseberries are most popular, though some markets prefer the pink or red varieties. The latter are often considered by retail customers as green-colored fruit that is overripe and therefore are discounted in desirability. However, this point may have been overemphasized, because the pink or red varieties often out-sell the green sorts.

For gooseberry mildew—If wet weather prevails make weekly applications of lime sulfur 2-100 until fruit begins to color. Omit poison.

For rust on black currants—Do not plant near white pines. Apply foliage sprays as above.

Table 40

SPRAY PROGRAM FOR CURRANTS AND GOOSEBERRIES (ONTARIO, CANADA SCHEDULE)

1st Spray	Currant aphids, scale insects	When buds are dormant or As the buds are bursting	Dinitro cresol powder 1½ lb. in 100 gal. 2% dormant oil emulsion (see below). Add dinitro last Homemade 3% dormant oil emulsion and Bordeaux 7½-10-100
2nd Spray	Leaf spots, mildew, currant sawfly	Just before blossoms open	On currants use Bordeaux 7½-10-100, lead arsenate 3¾ lb. On gooseberries use lime sulfur 2 gal., lead arsenate 3¾ lb., water to make 100 gal.
3rd Spray	Leaf spots, mildew, currant sawfly, rose stem girdler	Just after the fruit is set	Use same spray mixtures as in 2nd Spray
4th Spray	Leaf spots	Spray black currants ten days later. Spray red and white varieties immediately after the fruit is picked	Bordeaux 7½-10-100

For currant borer—Remove and burn dead or unthrifty canes annually before June 1. Careful pruning and fertilizer helps.

Dormant Oil Emulsion

Formula for 20-gallon stock emulsion:

Dormant oil	10 gal.
Water	10 gal.
Blood albumin emulsifier (50%)	2½ lb.

Method of Making Dormant Oil Emulsion

Pour the oil into the spray tank; make the blood albumin emulsifier into a thin paste with a small quantity of the water; put the paste and the remainder of the water into the tank and pump the mixture back upon itself through the nozzle under high pressure until all the oil is thoroughly emulsified. Pump out the stock emulsion into a clean container. Each two gallons of emulsion contains one gallon of oil. Six gallons of stock emulsion are required for 100 gallons of 3 per cent oil emulsion.

N. B. The stock emulsion will keep about one week in cool weather.

The dormant oil must have approximately the following characteristics:

Gravity (A.P.I.) at 60° F. . .	24_{25}
Viscosity (Say.) at 100° F. .	170_{220}.

FRUIT MAGGOT. Wormy currants and gooseberries are a very serious trouble in northern-midwestern areas, and nearly the entire crop is lost in some years. The damage is caused by the *currant fruit fly* which passes the winter as a pupa in the soil under the bushes. The flies begin to emerge when the currants are in full bloom. Egg laying does not start for another ten days, at which time most of the currant flowers are past bloom. The female fly inserts eggs into the young fruit by means of her ovipositor. The eggs hatch in about a week and the maggot commences to consume the surrounding tissue. The infested berries develop discolored areas about the spot where the egg was inserted and ripen unevenly and prematurely. Many drop from the bushes before the main crop is ripe, but others remain and are picked with the normal berries. The maggots leave the fruits soon after they fall and enter the soil to a depth of 1–2 inches, where they pupate.

Good control must be timed to kill the flies before they commence to lay eggs. They will feed on sweetened liquids if these are mixed with a poison and sprayed on the currant foliage. A safe poison is cryolite: e.g., cryolite, four pounds; molasses, 1½ quarts; water, 80 gallons. This is sprayed on the bushes just after blossom fall. It should be repeated two or three times at weekly intervals or oftener if rain washes the spray off the leaves. Arsenicals or DDT (plant form) give good control of the pest when used as a spray or dust, but may leave a poisonous residue on the fruit.

5. Blueberry Culture

A SIMPLE distinction between blueberries and huckleberries can be made on seed characteristics. In blueberries (*Vaccinium*), there are many very small, soft, inconspicuous seeds; in true huckleberries (Gaylussacia), there are 10 large, bony seeds. The "huckleberries" of most markets are, as a rule, fruit of one or more of the wild species of blueberries.

CHIEF SPECIES OF BLUEBERRIES

1. Lowbush or low sweet blueberry, *V. angustifolium* (*V. pennsylvanicum*)
2. Canada, sour-top, or velvet-leaf blueberry, *V. canadense*
3. Dryland blueberry, *V. pallidum*
4. Rabbiteye blueberry, *V. ashei*
5. Mountain blueberry, *V. membranaceum*
6. Evergreen blueberry, *V. ovatum*
7. Highbush or swamp blueberry, *V. australe*; *V. corymbosum*

Lowbush and Canada Blueberries

The plants are essentially wild. There are no named varieties, and little or no attempt is made at propagation, planting, pruning, cultivation, use of fertilizer, or other common horticultural practices. Many circumstances are tending to change the handling of the wild crop from an extensive to a more intensive type of culture. Chief among these are the market demand for a better canned product and the necessity of dusting or spraying to control the blueberry maggot and other pests.

The lowbush blueberries are upland species, usually 6–18 inches high, which stool into large colonies by means of underground shoots. The fruit is gathered for the canneries with special rakes, which are similar to the

cranberry scoop but smaller. The rake used in eastern Maine is 10–12 inches wide and has 18–40 teeth. For the fresh-fruit market the fruit is picked by hand as well as harvested with rakes. Even though only a part of the total wild crop is harvested, the annual value of the harvested fruit in Canada and the United States is probably over $3,000,000, the larger part being used by canneries.

MAINE. As a commercial development the blueberry industry in Washington and Hancock Counties, eastern Maine, began 60–70 years ago. Maine blueberries yield a return of about three million dollars; one million for fresh fruit and two million for the canned pack. The blueberry lands in eastern Maine consist of high, fairly level plateau land or of moderately sloping to steep, rocky hillsides. The soil is usually sandy, with a surface layer of organic matter. The coniferous forests that once covered most of this land have been removed. The present vegetation is characterized by typical acid-soil plants. Birch and alder sprouts and sweet fern are abundant on most of the blueberry land, and much labor is required to prevent these bushes from crowding out the blueberry plants.

Most of Maine's commercial production of blueberries is found on loamy, sandy, rather shallow soils that contain very little organic matter. These soils are acid, generally with a pH range of 4.4 to 5.7. Although the berry is found wild in all counties in Maine, commercial production has centralized in southeastern Maine within 20 miles of the seacoast. Here the average annual moisture precipitation amounts to about 40 inches. Temperature during the growing period ranges from 55° to 70° F. which is rarely exceeded. The average length of the growing season is 125–160 days.

NEW HAMPSHIRE. The wild blueberry crop in New Hampshire is greater than the total crop of raspberries, blackberries, currants, gooseberries, and cranberries combined, and is about half that of the strawberry. The largest shipping points are located at Lyndeborough, Fitzwilliam, Epsom, New Durham, Alton Bay, Troy, and Greenfield. The most successful blueberry farms are found on hardwood land at elevations of 1,000–2,000 feet. Especially favorable conditions are furnished when a fairly shallow and rather acid soil (pH 4.5 to 5.0) with a good underground supply of water overlies granite ledges. The use of a rake makes it possible for a good picker, in good picking, to harvest 20–25 bushels of berries in a day. Then these berries are run over a grading and cleaning machine

which leaves them free from leaves, bad berries, or anything else that interferes with the quality, hence they are literally untouched by hand as well as being handled cheaply. Cellophane covers are commonly used. In this area, it is doubtful that the highbush blueberries can compete with the lowbush in a commercial way.

MICHIGAN. There are areas suited to both lowbush and highbush blueberries. The line dividing the areas in which these two species are grown is rather distinct. It extends from Bay City, located near the lower end of Saginaw Bay, southwest across the state to a point about 20 miles north of Grand Rapids. As the line approaches Lake Michigan, it turns northwest to some extent, due, probably, to the moderating influence of the lake on the climate. South of this line the highbush blueberries are found growing naturally, and north of this line, including the Upper Peninsula, only the lowbush species are found.

OTHER AREAS IN THE UNITED STATES. In Massachusetts, the chief acreage of wild blueberries is in Worcester County. In New York, they are harvested chiefly in the eastern part, in Renssalaer County. Lowbush blueberries are also harvested in northern Wisconsin and northern Minnesota. In West Virginia, they are found chiefly on the vast expanses of comparatively level, rocky land located on the crest of the Allegheny Mountains. These areas,[201] in Pendleton, Tucker, Randolph, and Grant Counties, and bearing such names as Flat Rock Plains, Brushy Ridge, Red Creek Plains, and Roaring Plains, are a part of the Monongahela National Forest, are 3,000–4,800 feet above sea level, and cover an area of 250–300 square miles.

CANADA. Large quantities of the wild blueberry are harvested across Canada in the northern parts of its provinces. In Nova Scotia approximately 43,000 acres are devoted to blueberries in the western counties, e.g., Cumberland County; with the rotation of burning, two thirds of the acreage is in bearing each year; a large tonnage is canned and carload shipments of frozen berries are made. In Prince Edward Island wild blueberries are not commercialized as much as elsewhere but both soil and climate are suitable and the industry is expanding. In New Brunswick large areas have been burned over at various times and grow little else but blueberries and other heath plants. No complete estimate of the blueberry acreage is available, but in 1939 around 4,000,000 pounds were marketed, 2,500,000 from Gloucester County. In Charlotte County systematic care

of the blueberry barrens with burning every third year is a common practice. In Quebec, about 6,500,000 pounds return a value of about $600,000. The Lac St. Jean and Chicoutimi area is the most important source of this crop. Some other important areas in Quebec are Baie St. Paul and Saguenay, Abitibi, Trois Rivieres, Bas St. Laurent and Gaspesie, North Shore, and Joliette. A number of canneries and chilling plants are operating. There are large areas of wild blueberries in the Muskoka region and many northern sections in Ontario.

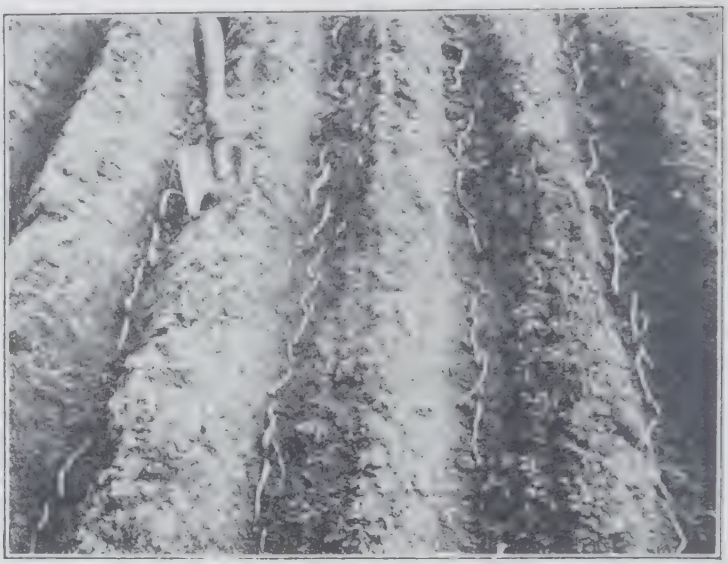
PROPAGATION

SEED. In nature, blueberry fruits are scattered about by birds, animals, and various other means. Occasionally a seed from these fruits germinates and develops into a new plant. Every patch of lowbush plants starts in this manner from seed. No two plants originating from seed are exactly alike. It is easy to grow blueberry plants from seed. Care must be taken, however, not to let the seed become dry before sowing; otherwise it goes into a rest period that often requires two years to break.[440] Since the rest period commences at harvest time, it is well to take the added precaution of chilling the berries at freezing temperatures for several days, as well as keeping them moist.

After this chilling to break the rest period, the skins are removed and the pulp which contains as many as 200 seeds is planted immediately. This pulp keeps the seed moist until it germinates. The pulp masses are sown $\frac{1}{4}$ inch deep in flats with a mixture of sand and fine peat moss. Many fine seedlings will emerge from each pulp mass. While still very small (6–7 weeks old and with two leaves) the seedlings are teased apart with a needle, set in rows in another flat, and then shifted again when they become crowded.

After the plants have developed several leaves, fine peat is sprinkled over them. They may be grown indoors in the flats all winter. Thus, quite sizeable plants may be obtained by spring from fruits harvested the previous year. Another method is to place them in a pit over winter. This protects the plants, preventing frost from heaving and breaking the tiny roots. Plants so handled are so small that they should remain in flats until spring of the next year.

Certain advantages and drawbacks of shredded sphagnum over peat and peat sand as a medium for growing blueberry seedlings have been



Propagation of the low-bush blueberry by the underground stem method. (Courtesy, F. B. Chandler, Maine Agr. Exp. Sta.)

found.[97] Sphagnum is somewhat more expensive than peat-sand mixture as a rooting medium, and pricking-off into this is slower and more difficult. Also, shredding the sphagnum is a tedious and disagreeable task if a hammer mill is not available. If the sphagnum is placed where it will dry out thoroughly, shredding is greatly facilitated. For experimental work the advantages outweigh the disadvantages. Watering is easily done since it is almost impossible to overwater; the plants can be moved several times, even in wooden bands, without disturbing the roots system; and the additional growth made is highly important in obtaining fruiting plants as quickly as possible.

RHIZOMES. The lowbush blueberry plant sends out rhizomes from the crown which grow underground a short distance, then push up through the soil to form new plants. Roots soon form on the rhizomes and the new plant becomes independent of the mother plant. A single plant multiplies each year, forming a patch or clon. The new plants thus formed are identical with the parent from which they originated.

A clon producing a desirable berry may be cut into strips and taken up much as turf is handled for sodding lawns. The soil is shaken off and the rhizomes cut into three-inch lengths. From a square foot of such "sod" usually about 100 cuttings can be made. In the nursery, the cuttings are

laid end to end in furrows about six inches apart and covered with 2–3 inches of soil. Spring planting is better than fall because of heaving. After a year in the nursery the plants can be set in the permanent location. Any part of the rhizome can be used, but smaller diameter cuttings are more likely to grow. The inferiority of the large cuttings is because of fewer active rootlets. In those with tops attached, the larger transpiring surface is also a factor. Sandy soil, where the plants grow naturally, is good rooting material. This method is of limited value until the plants are several years old, when the rhizomes become sufficiently large and numerous to yield a fairly large number of cuttings.

CUTTINGS. The lowbush blueberry can be propagated from both hard- and soft-wood cuttings made from vigorous new shoots. The cuttings are probably best rooted in peat in special propagating frames. Small side shoots can also be used.[277]

TRANSPLANTING. Another method of getting a stand of wild plants is to dig up the patch of blueberries and separate out the individual plants which are then cut back to 2–3 inches and set in trenches. The crown of each plant is barely covered with soil. But, though many attempts have been made, especially in Michigan and Maine, to establish lowbush blueberry plants by this method, the results generally have been disappointing chiefly because of the slowness with which the plants spread out and fill in the area.

BURNING. Lowbush blueberry land receives little care except for some mowing of the weed bushes, and systematic burning. As the blossoms and fruit of the lowbush blueberry are borne on the growth of the previous year, a large proportion of strong, new shoots is needed, and these are encouraged by severe pruning. Fire has been accepted as the simplest method of removing this old growth and therefore it is customary to divide the area into three parts, burning one-third each year. The burning plays a role in weed and insect control and in pruning. The system of burning once in two years results in a crop of fruit every other year; burning once in three years results in two crops in three years. The usual procedure is to spread hay over the land in the fall and to burn it in early spring while snow is still lingering in the woods as a fire protection, and before the green grass appears. The winter snows crush the mulch around the old stems, thus aiding in a thorough clean-up. Where it is difficult to obtain hay the burning may be done with oil.

It is because the aboveground portion of the lowbush blueberry forms only a small part of the total that the blueberry is less damaged by burning than is most of the competing vegetation. Its extensive root system allows the plant to compete well with other plant forms on land of low fertility level.

When blueberry plants are burned the new growth comes from the buds on the underground stem. Usually there is an average of less than two new stems for each old stem. Fifteen months or so must elapse between burning and the harvesting of the blueberry crop. The first crop, which is obtained the first year after pruning, is much larger than the succeeding crops in fields where *V. angustifolium* is the predominant species. Where *V. canadense* predominates the second crop may be larger than the first. Firing more often than once in three years seems to destroy too much humus and a longer interval between burnings reduces the yield.

An experiment in Maine[55] showed that two-year burning over a period of years would cost 50 per cent more than three-year burning and cause a decrease in yield; therefore, two-year burning is not ordinarily recommended. For the best plant spread, the plants should be burned when set and every three years thereafter. Plants which are burned spread more than plants which are cut or cut and covered with soil. Burning the entire area without leaving any "islands" is important as the old plants form a refuge for maggots and other insects. From the viewpoint of soil management, burning is an undesirable practice as it removes organic matter and nitrogen from the soil and eventually results in decreased yields. Mixing peat, equivalent to one inch over the surface, with the top soil increased the spread of the plants. This peat treatment or growing several crops of buckwheat and cultivating it into the soil increased the number of stems.

Although it is a common practice in some commercial fields in Maine to spread hay on the blueberry plants in order to get a good burn, most of the good blueberry pastures in New Hampshire are at high elevations on mountain slopes where the cost of spreading hay is prohibitive.

Fertilizer. In Maine, when the soil fertility is raised, quick-growing grasses and annuals, unless rigidly controlled, often crowd and shade out the blueberry.

In New Hampshire,[41] examination of the surface soil from high producing areas has shown it to be composed of a one-inch duff made up largely of roots, dead and decaying twigs and leaves, whereas in the low

producing areas the layer of duff is missing or very thin. When burning is done once in three years, an area that has been in production for 60 years may have been burned as many as 20 times, which, because the duff is inflammable, and accompanied by normal decomposition, probably is responsible for the low organic content of the soil. There is no consistent difference in soil acidity between the high and the low yielding areas; both are around 4.5. The plants on the low yielding areas are much shorter and a lower proportion of the stem forms fruit buds.

May and June applications in New Hampshire of 7-7-7 fertilizer at the rates of 200, 500, and 1,000 pounds per acre, respectively, have greatly increased the yield of lowbush blueberries. Increased yield on fertilized plants appears to be due primarily to larger numbers of fruit-bud clusters and more fruit buds per cluster. Application of the complete fertilizer to plants with three-year old tops lengthened their productive period from 3–5 years, and possibly six years. Nitrate fertilizers alone applied at the rate of 200, 500, and 1,000 pounds per acre produced excessive growth of weeds and grass as well as blueberry stems, with a slight increase in yield of fruit.

Classification of Lands and Yield. In Washington and Hancock Counties, Maine,[820] blueberry land has been classified into four groups: "Barrens," large areas of cut-over land that have been severely burned by fires; "Field," land formerly in cultivated crops; "Pasture," land previously used for pasture; and, "Woodland," land comparatively recently in woods. "Barrens" averaged 1.16 bushels per acre for the crop following the burn and 0.38 bushels for the crop the second year after the burn. The yields on "Field" were 19.5, 12.1, and 1.25 bushels for the first, second, and third crops; for "Pasture" they were 14.5, 12.3, and 2.5 bushels, and, for "Woodland," 11.9, 7.9, and 2.9 bushels. The yield increased with the age of the bushes to approximately 30 years, then it decreased slightly. The yield per acre was directly related to the percentage stand of bushes. The first and second crops on all classes of land (except "Barrens") averaged 7.5 bushels on land with less than 34 per cent stand; 11.9 bushels, 34 to 68 per cent stand; and 15.2 bushels on stands of 68 per cent and over. Thoroughness of burn was fully as important as percentage stand of bushes. When land was burned once in three years, which resulted in the highest yields, "Barrens" showed the highest cost and the lowest gain per bushel; whereas "Field" had the lowest cost and the highest gain.

DRYLAND BLUEBERRIES

The dryland blueberry, or "low huckleberry," is native from Georgia and Alabama to Maine and westward to Michigan and Oklahoma, but it is important chiefly in northeastern Alabama, northwestern Georgia, West Virginia, and western and northwestern Arkansas. The plants grow in the dry, relatively poor soils of the ridges and hills and are very drought-resistant. The dryland blueberry grows 1–3 feet high and spreads in colonies much as does the lowbush blueberry. The berries are light-blue and their flavor is good.

The dryland blueberry commonly ripens later than either the lowbush or the highbush and is sometimes called the late blueberry. However, in Georgia and Alabama it ripens before the crop from cultivated fields in New Jersey. The annual value of the harvested crop, all from wild plants, averages $300,000; in some years it is much more. No varieties of the dryland blueberry have been named and introduced. The usual low form of this blueberry does not hybridize with the highbush. However, vigorous taller plants of this general type that bear larger berries than the usual low form and do cross with the highbush varieties have been found in Georgia and Alabama. This large-fruited dryland blueberry may become the more important commercially in those states.

EVERGREEN BLUEBERRY

The evergreen blueberry is native along the Pacific coast from central California to British Columbia. The fruit is gathered extensively in northern California, along the coast of Oregon and Washington, and in the Puget Sound district. Branches of this blueberry are important commercially for decorative purposes, being shipped by the carload to eastern cities as "evergreen huckleberry," chiefly from December to March. The branches for shipment are gathered in open woodland where there is partial shade. The plant is also an attractive shrub in flower and fruit as well as in leaf. It may reach a height of 20 feet in open woods. No commercial plantings for fruit production are known. The annual value of the fruit crop is about $150,000 to $200,000 and that of branches an equal amount.

The berries ripen from August to November, but the chief shipments are made in September and October. The berries are usually small and

shiny black with a strong flavor not at all like that of other blueberries. This flavor makes them less desirable than other blueberries for eating fresh. However, they are much used for pies and otherwise in cooking. A variation with slightly bluish fruit is not uncommon. A large part of the crop is frozen for use by pie-makers.

This blueberry has not been hardy in the eastern United States where tested. Cuttings, 6–8 inches long, with 4 6 of the upper leaves left on, taken during winter, are readily rooted.

MOUNTAIN BLUEBERRY

The mountain blueberry, or "broadleafed huckleberry," is a native of the high slopes of the Cascade Mountains of Oregon and Washington and eastward to Wisconsin. It is common near Crater Lake, Mt. Hood, Mt. Adams, and Mt. Rainier, where thousands of visitors pick the fruit each year. It is a very drought-resistant plant and matures its fruit in the late summer even after three or four rainless months. The plants grow 3–5 feet high and are abundant in burned-over areas. In the Cascade Mountain area at least it is one of the best flavored and uniformly largest fruited of all wild blueberries. The annual value of the fruit crop is about $200,000. The berries are somewhat pear-shaped, black or maroon in color, juicy, high-flavored, and rather tart but not too tart to be eaten fresh. Because its berries are borne singly* or in pairs rather than in clusters like those of the other blueberries, the individual bushes are not highly productive and are not likely to become important under cultivation.

RABBITEYE BLUEBERRY

The rabbiteye blueberry is native to river valleys and the edge of woods in southern Georgia, southern Alabama, and northern Florida. It grows on locations with more upland conditions than the highbush. Also, it is not so sensitive to soil acidity and is far more heat- and drought-resistant than the highbush. More than 3,500 acres located mostly in northwestern Florida, but also in North Carolina, South Carolina, Georgia, Alabama, Mississippi, and Louisiana, have been planted to this species, the plants having been moved from the wild into commercial fields.

Because much fruit shipped from the South has come from the unselected bushes, many of which produce small, gritty-fleshed berries,

* Blueberries which bear their fruit singly are sometimes called whortleberries.

lacking in flavor, the rabbiteye has had a poor reputation in markets. The berries are mostly black and not so attractive as the blue-fruited kinds. However, some named rabbiteye varieties bear large, juicy, aromatic, blue fruit, which compares favorably with that of selections of other species.

Table 41

RABBITEYE BLUEBERRY VARIETIES RANKED APPROXIMATELY IN ORDER OF IMPORTANCE WITH REFERENCE TO CERTAIN CHARACTERISTICS[183]

Rank	*Season (early to late)*	*Size of Berry (large to small)*	*Dessert Quality (good to poorer)*	*Color (light blue to black)*	*Suckers (many to few)*
1	Ruby	Ruby	Clara	Ruby	Myers
2	Hagood	Black Giant	Myers	Myers	Hagood
3	Jean	Owens	Scott	Clara	Jean
4	Black Giant	Jean	Owens	Suwanee	Ruby
5	Myers	Hagood	Jean	Jean	Suwanee
6	Clara	Clara	Black Giant	Owens	Scott
7	Suwanee	Scott	Hagood	Scott	Owens
8	Owens	Myers	Suwanee	Hagood	Black Giant
9	Scott	Suwanee	Ruby	Black Giant	Clara

The commercial growing of blueberries in northwestern Florida had its inception in a planting made about 1893 near Crestview, Okaloosa County, by M. A. Sapp, with bushes transplanted from the wild. Between 1920 and 1930, 2,225 acres in Florida were set with plants moved from the wild or propagated from the early plantings and selections. Similar plantings were made in Louisiana, Mississippi, Alabama, Georgia, South Carolina, and North Carolina. Few of these plantings were made with selected bushes, and since 1930 relatively few of them have been cultivated. The crop of the rabbiteye is nearly all from such plantings and very little from the wild. Plantings of 50–100 acres are not uncommon.

REST PERIOD. Highbush varieties do not get enough cold "rest period" in southern Georgia in the average winter and usually die without producing any fruit. However, the rabbiteye variety "Pecan" requires less than one third the cold period of the highbush,[185] and is far better adapted to regions like southern Georgia and northern Florida. It corresponds to the Peento peach in that slight cold will break the rest period. Other rabbiteye varieties may have shorter or longer winter rest requirements than does the "Pecan."

TREATMENT AND YIELD. The rabbiteye blueberries are generally set in

midwinter about 15 × 15 feet. Under good conditions they grow rapidly and bear commercial crops by the third year. They respond to cultivation or mulching and use of fertilizer. In one planting in southern Georgia, the average annual yield of the Black Giant for the first 11 years of bearing age was nine quarts per plant; in the eleventh year the yield was 30 quarts per plant. In Florida,[339] when large plants are used and growth is thrifty, some fruit is borne the second year after transplanting, but commercial quantities should not be expected until the third or fourth year. Thrifty plants should produce 4–7 quarts of fruit by the fifth or sixth year, the yield increasing until the plants are 12–15 years old. If the planting is properly located and given good attention, an average of 12–16 quarts per plant should be produced by the tenth to twelfth year. Higher yields have been reported. Individual plants 11–15 years old have produced 50–60 quarts of fruit in a year, but such yields are exceptional.

Pruning is not generally practiced, but the fruiting habit of the rabbiteye resembles that of the highbush blueberry and some pruning of older bushes is desirable. The older stems and the smaller young shoots may need thinning to prevent the bushes from becoming too dense; pruning should be relatively light, however, because the rabbiteye blueberry is sufficiently vigorous to support and bring to large size large crops of fruit.

Harvesting. Picking in north Florida usually begins late in May. Normally, only a few berries in a cluster ripen at one time. Some varieties ripen most of their fruit within a 30-day period; others may ripen over a period of three months, extending into September. The rabbiteye blueberry has firmer fruit with a much smaller scar where the berry is picked from the stem than the highbush blueberry, and so withstands shipment better.

Propagation. This is done chiefly by offshoots, or suckers, which arise at distances of a few inches to eight feet from the parent plant. New plants can be obtained from these suckers if they are removed during the dormant season with some root attached. They may be set directly in the field or, if small, may be grown for a year in a nursery row.

Cuttings taken at the time of, or just before, the cyclic period characterized by the cessation of shoot growth and the initiation of root growth in the parent plant root very successfully. The most favorable time for rooting is from April 20 to May 20 in northern Mississippi. The propagation period is earlier farther north and is later farther south. Cuttings can be made from the time the newly produced shoots have passed the early,

succulent period up to the time they approach the end of their growth period. There is a second period in early September when a fair percentage of cuttings may be expected to root in Mississippi. Small shoots make the best cuttings, and an increase in leaf area up to two square inches per cutting gives a corresponding increase in root development and secondary top growth. A rooting medium of equal volumes of peat and sand is satisfactory, and probably the proportion of sand should be increased after June 1.

HIGHBUSH BLUEBERRIES

In the highbush blueberry, new terminal shoot growth is added to the canes each year, thereby forming a tall bush. The individual canes may persist for many years and become thick and tall. Eventually the older canes die and are replaced by younger ones coming up from the crown. Old canes are relatively unproductive and yield only small-sized berries. The highbush plant does not spread by rhizomes like the lowbush plant.

There are about 2,000 acres of cultivated blueberries in New Jersey, 500 in North Carolina, 500 in Michigan, and possibly 700 in Washington, Oregon (in the coastal region, e.g., near Newport), Massachusetts, and New York. The annual value is about $2,000,000. Most varieties are not adapted to conditions south of northern Georgia, probably because of high temperatures and short days. In Canada about 50 acres of highbush blueberries are grown commercially in British Columbia, chiefly on Lulu Island and the Lower Fraser Valley; small plantings occur in Nova Scotia, e.g., Kentville, and in Ontario.

HISTORY. Serious attempts to cultivate the highbush blueberry did not occur until 1906, when Dr. F. V. Colville, U.S. Department of Agriculture, began experiments on the requirements for culture, propagation, and breeding. Beginning in 1911, Joseph J. White, Inc., with its treasurer, Miss Elizabeth C. White, as the active worker, cooperated in this work at Whitesbog, N. J., and this area became outstanding in blueberry development and industry. Later, larger areas in other districts were developed.

CHARACTERISTICS OF CULTIVATED BLUEBERRY VARIETIES

ATLANTIC. Jersey x Pioneer. Bush very vigorous, open spreading, fruit cluster loose. Late. Promising for large size, fine color, and good scar of fruit and yield. Introduced in 1939.

BURLINGTON. Rubel x Pioneer. Bush vigorous, upright spreading, fruit cluster

The Jersey blueberry, one of the largest in cultivation. (Courtesy, Miss Elizabeth C. White, Joseph J. White, Inc., Whitesbog, N. J.)

medium tight; berry medium size, good dessert quality. Late. Promising for its fine blue color, and its fine scar superior to that of most other highbush varieties. Introduced in 1939.

CABOT. Brooks x Chatsworth. Bush below average in vigor, low spreading; fruit cluster long, tight; berry small to medium, not very firm, of poor texture, usually only fair in dessert quality except in Michigan and the Northeast; scar fair; season early and long, first ripening usually just after Weymouth and June and last pickings with Jersey and Rubel, more satisfactory in the North than in North Carolina and New Jersey. Introduced in 1920.

DIXI. (Jersey x Pioneer) x Stanley. Bush vigorous, open spreading. Fruit cluster medium loose. Late, slightly before Jersey. Promising for its large size, good dessert quality, and yield but with a poorer scar than Atlantic and Jersey. Introduced in 1936.

JERSEY. Rubel x Grover. Bush above average in vigor, erect, productive. Liked for its vigorous fine bush, great resistance to stem canker in North Carolina, open fruit cluster and large berry. Late. Introduced in 1928.

JUNE. (Brooks x Russell) x Rubel. Bush below average in vigor, erect. Fruit cluster loose. Berry medium size, medium dessert quality, scar medium, very early, usually picked in three pickings. Liked for its early ripening, but plants weakened by leaf drop following spot. Introduced in 1930.

PEMBERTON. Katherine x Rubel. Bush very vigorous, erect, and productive. Fruit cluster very loose. Very dark, good dessert quality; scar poor, late (slightly before Jersey and Rubel), somewhat hard to pick. Introduced in 1939.

PIONEER. Brooks x Sooy. Bush open spreading, vigorous. Fruit cluster long and rather tight. Berry medium size but large if heavily pruned, darker than Cabot; scar medium size; midseason to nearly as late as Rubel. Liked in New England and Michigan because of its yield and good flavor, but being discarded in New Jersey and North Carolina because of its uncertain yield and in North Carolina also because of susceptibility to stunt, stem canker, and mite. Introduced in 1920.

Table 42

BLUEBERRY COSTS OF PRODUCTION. MICHIGAN[531]

Item	*Costs per Acre*		*Costs per Pint (average 1929 pints per acre)*
	Amount	*Value*	
Overhead costs			
Depreciation in plantation value	..	$ 1.94	.1 cents
Interest on plantation value @ 5%	..	35.00	1.8
Share of general farm expense	..	13.75	.7
Management charge	..	24.24	1.3
Total	..	$ 74.93	3.9 cents
Growing costs			
Man labor	94.8 hrs.	$ 53.03	2.7 cents
Power and equipment use			
Tractor	6.6 hrs.	5.35	.3
Truck	N. A.	4.98	.3
Sprayer	..	.19	.0
Other equipment*	..	3.01	.2
Horse work	..	1.29	.0
Total	..	14.82	.8
Materials used			
Fertilizer	N. A.	5.29	.3
Spray material	N. A.	.78	.0
Other†	..	1.84	.1
Total	..	7.91	.4
Total	..	$ 75.76	3.9 cents
Harvesting and marketing costs			
Picking labor	279.0 hrs.	$139.04	7.2 cents
Packing and marketing labor	47.4	23.22	1.2
Truck use	N. A.	4.28	.2
Packages	..	49.32	2.6
Association charges	..	106.50	5.5
Total	..	$323.04	16.7
Total cost	..	$473.69	24.5 cents

* Includes car use.

† Cover crop seed, lime, etc.

RANCOCAS. (Brooks x Russell) x Rubel. Bush erect, of medium vigor. Fruit cluster very tight. Berry medium size, medium dessert quality; scar medium size; early midseason. Subject to June spot and drop in summer in Michigan, but liked elsewhere for its yield and resistance to stem canker and stunt. Introduced in 1926.

RUBEL. Selection from wild. Bush erect, vigorous, productive. Fruit cluster very loose. Berry small to medium, medium in dessert quality; scar good, late.

STANLEY. Katherine x Rubel. Bush erect, vigorous, but with few main branches. Fruit cluster medium loose. Berry of high dessert quality; scar medium-sized to above; midseason, ripening just after Rancocas. Though very aromatic the berries usually are not very large, and later ones to ripen often very small; liked where berries are of good size. Introduced in 1930.

WEYMOUTH. June x Cabot. Bush erect, often spreading, of average vigor. Fruit cluster medium loose; scar medium; earliest of all, ripening all berries quickly. Planted extensively for early season, but dark, not of high quality, and lacking aroma. Introduced in 1936.

PROPOGATION OF HIGHBUSH BLUEBERRIES

The blueberry is not so easy to propagate as are many other plants, but with careful attention it is propagated extensively by either hardwood or softwood cuttings. Propagators have been getting 50 to 80 per cent of the cuttings to grow.

Rancocas, Rubel, and Pemberton are relatively easy to root from cuttings; Jersey, Pioneer, Concord, and Scammell are somewhat less so; and June, Atlantic, and Stanley are more difficult.

HARDWOOD CUTTINGS. Firm, well-rounded, medium to medium large, sturdy shoots of the past summer's growth, taken in late winter or early spring, furnish the cutting wood. The portion bearing only leaf buds is most commonly selected, but if cutting wood is scarce or especially valuable, sections with an occasional fruit bud may be used. Shoots from which cuttings are to be made are commonly 12–30 inches long. These "whips" may or may not have fruit buds at the tip, but they must be sound and well-hardened. Small, slender shoots, as well as poorly hardened pithy growth made during late summer should be avoided. Browning of the pith is a sign of inferior wood and is most likely to occur in poorly hardened growth. If "stunt" is present in a field, one should take cuttings only at a distance of at least 50 feet from the nearest diseased plant.

A propagating frame as commonly used in Michigan[278] measures six feet long, 27 inches wide, and 16 inches high. Dimensions for length and width may be changed to accommodate glass sash of various sizes that may be on hand. The cutting tray is made of four-inch lumber with $\frac{1}{8}$- or

The blueberry shoot at the left shows winter injury; beside it is another showing the extent of the injury. The shoot in the center is undesirable for cuttings because of the prevalence of fruit buds. The shoot at the right illustrates the best type of wood to use for hardwood cuttings. At the extreme right is a hardwood cutting ready for planting. (Courtesy, S. Johnston, Michigan Agr. Exp. Sta.)

1/4-inch mesh hardware cloth stapled on the underside. This tray rests on braces nailed on the inside of the frame eight inches from the top. It can be removed without disturbing the cuttings, which facilitates handling. After the cuttings are planted the glass sash and shade are placed on top of the frame. Burlap makes good shading material and provides just about the right amount of light. Closer or looser woven materials should not be used. The propagating frames should be located in the open sunlight, well removed from buildings and trees. The medium may be a mixture of sand and ground sphagnum peat moss, half and half. In Michigan and other northern areas glass-covered beds are used, but to the south, e.g., in New Jersey, an entire series of beds, commonly four feet wide and six inches deep after settling, may be covered with a lath house about seven feet high.

The ideal procedure in New Jersey,[198] when operations are small, is to take the cutting wood from the parent plant between April 1 and 15, make the cuttings, and set them directly in the propagating bed. But, when large amounts of wood must be gathered and made up into cuttings, or when wood is purchased and must be obtained far in advance, storage for a considerable period becomes necessary. Under these conditions the gathering of cutting wood is frequently begun in February. Unless cold storage is used, earlier gathering is not advisable. Storage exposes the material to drying out or molding and blackening.

If kept cool (35° to 40° F.), moist, and well aerated, the whips retain life and vitality very well. Light freezing does little harm, but may necessitate greater care against drying out of the wood. The whips may be stored in boxes, with loose moist, but not soggy, sphagnum moss.

Making cuttings is a time-consuming job and because whips keep better than cuttings in storage, the work is usually delayed as long as possible. But, it is important to be ready at setting-out time. The whips are cut into pieces 3–4½ inches long. The top cut is best made just above a leaf bud. With difficult-rooting varieties, e.g., June, it is important to make the bottom cut close below a bud, and, in fact, it is common practice to make the lower cut at a slant just beneath the lowest bud. Often the upper portion of the whips is of late growth, and the wood there is not so round, stout, or firm as the lower sections. That portion of the whip will not root readily and should be discarded. When the cuttings are made they are placed in the moss, with all buds pointing one way.

In southern New Jersey, cuttings are set in beds about April 1, before the buds enlarge so much that they may be injured by the necessary handling. In common storage this swelling is likely to occur about April 15. The cuttings are pushed into the bed, preferably in a vertical position, usually in rows two inches apart with the individual cuttings one inch apart in the row. Only the top bud of the cutting is left above the surface or even with the surface of the soil.

The cuttings soon develop leafy stems 1–3 inches long. Then, in the summer growth stops and root formation starts. After the root growth is established, the tops start new terminal growth. The first greening of the tips, which heralds this second growth, is the sign that rooting has taken place.

Although injury has resulted in some cases where fertilizer has been added to the ground peat moss, strong growth in the propagating bed

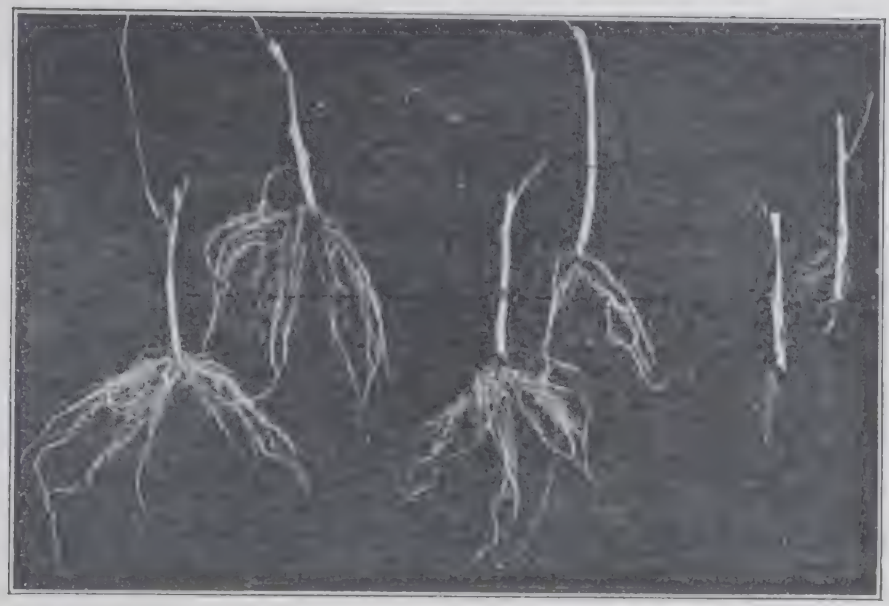
can often be obtained by the use of fertilizer solution on the rooted plants. For this purpose a stock solution is made up as follows: one pound nitrate of soda; $\frac{1}{2}$ pound superphosphate; $\frac{1}{4}$ pound sulfate of potash; eight gallons water. This is diluted at the rate of one quart stock solution to two gallons water per 50 square feet of propagating bed. Apply with a sprinkling can, and rinse the foliage with water. The first application is made after the cuttings have rooted, and repeated weekly until late summer. If unusual conditions cause a rank growth, fertilizing should be stopped earlier in order to ensure well-hardened plants for winter.

A softwood cutting ready for planting in the cutting bed. (Courtesy, S. Johnston, Michigan Agr. Exp. Sta.)

The plants are left in the propagating bed over winter and moved to nursery rows in the spring. The nursery should resemble the location of blueberry crops. The rows may be 18 inches apart and the cuttings set out one foot apart in the row. To store cuttings over winter in Michigan,[278] in October or early November a trench four inches deep and wide enough to accommodate the trays of cuttings is prepared. After the trays are placed in the trench, all open spaces are filled in with soil. A closely woven wire fence keeps dogs, cats, and rabbits out of the trays during the winter.

SOFTWOOD CUTTINGS. These are made when secondary growth first appears on the new shoots. If cuttings are to be used untreated, they should be taken not later than two or three weeks before the first berries ripen. Whether taken then or later, and especially if taken later, up to the time that the first berries ripen, the rooting of cuttings is sufficiently hastened by root-inducing substances to warrant their use. Indolebutyric acid is effective with cuttings taken early,[279] less so or not at all with those taken later; indolepropionic acid is preferred for cuttings taken relatively late. These substances can be obtained under trade names in properly diluted solution or powder forms.

The cuttings are made about four inches long, and only the two upper leaves are retained. The upper half of each of the two leaves is usually cut off to reduce transpiration. A mixture of sphagnum peat and sand provides a good medium.



Softwood cuttings rooted in American peat, German peat, and sand. The two at the left were rooted in American peat, the two in the center in German peat, and the two at the right in sand. (Courtesy, S. Johnston, Michigan Agr. Exp. Sta.)

Planting Highbush Blueberries

Site and Soil. Rich garden soils or fertile fields are generally unsuitable. Basic soil requirements for best growth are an acid reaction, good drainage, and constant but moderate moisture. Blueberry plants are usually found growing in the wild state on soils ranging from sand to peat. For some time it was thought that they would not grow on a clay soil. However, it is now known that blueberry plants will grow well on such a soil provided it is sufficiently acid. Apparently, though, most areas of naturally suitable blueberry soils are of a sandy or peaty nature.

Highbush blueberries often grow wild along the edges of ponds and even in swamps. This situation gives rise to the belief that a bog or swamp is the proper place to grow cultivated blueberries; but the idea is erroneous. Careful observation shows that blueberries growing in swampy regions are located on hummocks so that the plants are raised a foot or more above the water level and roots are never completely submerged in the water throughout the year. A too high watertable caused by an impervious clay subsoil near the surface is undesirable; the watertable should be at least 14–22 inches below the surface. Dormant plants will tolerate

standing water, but during the growing season an excess of water is likely to be fatal. A soil which dries out, even for short periods, during the summer is not suitable unless some method of supplying water is provided. Insufficient soil moisture results in lack of fruit bud formation, and, if the deficiency is great, in the injury or death of the plants.

The blueberry requires an acid soil but just how acid is uncertain. Though a soil reaction of pH 4.5 to 5.0 is supposed to be best for blueberries this range may be at least widened to pH 4.0 to 5.5. Variation in growth on different soils within the latter ranges seems to be more closely associated with one or more soil factors than with soil acidity. It is practicable to make soils testing below pH 4.0 suitable for blueberry production by applying limestone at the rate of one to four tons per acre, depending upon the degree of soil acidity to be corrected. If possible, the limestone should be worked into the soil before planting.

Several materials may be used to increase soil acidity, including sulfur, crude tannic acid, and acid peat. None of these can be recommended for commercial use because of the expense involved and the uncertainty of lasting results. They may be used for small home plantings. If the soil is

Cultivated blueberry cluster. The largest berries are $\frac{3}{4}$ to $\frac{7}{8}$ inch in diameter. The illustration shows the glossy foliage which is suitable for garden and shrubbery. Jersey variety. (Courtesy, Miss Elizabeth C. White, Joseph J. White, Inc., Whitesbog, N. J.)

barely acid enough for best results in commercial plantings, sulfate of ammonia should be used in the fertilizer mixture rather than nitrate of soda.

Study in Rhode Island[57] and Maine[58] throws doubt on the generally accepted idea that blueberries in all cases require a distinctly acid soil, and indicates that they may, under certain conditions, grow well within rather wide pH limits. This latter conclusion seems to be true especially where plant nutrients are present in adequate amounts throughout the growing period, as they are when nutrient solutions are applied daily in watering or by drip culture methods. The results may also raise the question of whether or not a neutral soil condition is detrimental by itself, or because it interferes with the release or absorption of certain nutrients, as, for instance, potash, when such nutrients are present in insufficiently available or inadequate quantities. There seems to be a definite indication that nitrogen is an important element in the maintenance of healthy vigorous growth; also that blueberries respond favorably to a relatively abundant supply of organic matter, especially of the leafmold type, in the soil.

The land in southern New Jersey[60] used successfully for cultivated blueberries ranges from pH 4 to 5.5. On this land originally there was a surface layer of shallow forest peat 3–5 inches thick on top of apparently pure sand. This peat, in an early stage of decomposition, is characterized by coarse particles and still recognizable plant tissues. A coarse sand base is preferable but when other conditions are especially favorable, fine sand is satisfactory. A very definite hardpan at a depth of 20–30 inches helps to keep the soil moist above that depth. Such soils are known as St. Johns sand, Leon sand, or swamp. Plants set in virgin soil usually have grown best, probably because of the more fluffy nature of the peat. Wild plants growing on a proposed site can be used as indicators of adaptability to blueberries. A mixture of pine, red maple, and white cedar grows on a peat 4–8 inches thick and indicates a rich blueberry soil. Pure stands of white cedar indicate deeper peat that is not entirely satisfactory for blueberries because of the difficulty in draining and cultivating properly. Pine and oak forests indicate land that is too dry for blueberries. Sites covered with thin pine growth with a ground covering of sheep laurel can be used but, even with irrigation, such land will show its scarcity of peat a few years after planting. High sandy land is unsatisfactory.

Old cranberry bogs with a peat layer less than six inches thick have been plowed up and used to advantage for blueberry fields, but cleared land used for other crops usually has been drained and tilled so thoroughly

that the peat has disappeared and therefore this type of soil is generally unsuitable.

Plants set on thin land with a meager water supply may do well for several years, but after the bushes attain full growth, the shortage of both moisture and peat may cause trouble for the grower first in the poorest parts and eventually in the whole field. Other factors being equal, blueberry plants increase in growth and yield in direct proportion to increased humus in the soil.

The main commercial plantings in British Columbia are on pure peat. The total area available of peatland exceeds 40,000 acres. It is covered with a variety of vegetation, much of which consists of young pine trees and native species of cranberry and lowbush blueberries. The watertable is 1–3 feet from the surface, and so some drainage by open ditches is necessary. Gates in ditches should be arranged to control runoff water. Under such conditions soil to within an inch or so of the surface is always moist. During the winter and early part of the growing season the watertable should not be higher than 14 inches from the surface and during the picking season a two-foot watertable is satisfactory. The pH of the soil and water is in both cases less than 4. In preparation for planting, land must first be cleared of trees and stumps and much of the surface growth may be burned off when care is taken to prevent deep fires. The area may then be plowed and disked for a full year before planting in order to kill the native growth or the top four inches, which is the approximate depth of root penetration, may be skinned off by cutting the surface into narrow strips two feet wide and four inches deep and then grubbing this layer off with a potato hook. For initial planting this procedure may be modified by cutting out two-foot strips every six feet and plants may then be set. Later the area between rows should be cleared off.

Cold Injury. To obtain proper soil moisture requirements, it is usually necessary to establish the planting on comparatively low land that is more subject to frost than higher land. Wide, open areas permitting free movement of air should be chosen. The likelihood of frost damage can be decreased somewhat by clearing off the woods around the field to allow better air movement. Avoid valleys or depressions with hills close by. Nearness to large, deep bodies of water is added insurance against frost.

In low spots drainage may be poor and may cause late succulent

growth that will not be well matured for winter. Usually frost injury is limited to the killing of the flowers while the plants are in bloom, though the partially developed berries may also be injured. In Michigan, blueberry flowers in full bloom were not injured at 25° F., but 21° F. reduced the yield of Rubel 12 per cent and of Cabot 50 per cent. In a wild blueberry swamp half the crop was destroyed by 19° F.

Where the blueberries are growing on an old cranberry bog and there is a supply of water available, the danger of frost may be decreased by partial flooding on cold nights after growth has started.

POLLINATION. A grower may expect earlier ripening and an increase in set and size of fruit in proportion to the degree of self-incompatability of the variety in question and to physical factors entering into cross-pollination. For example, since eastern North Carolina growers are interested in early maturing large-sized fruit, the present practice of providing for mixed variety plantings not only aids in obtaining a better set, but also helps to provide earlier ripening and a better grade of berries. On the other hand, growers in regions with a good late market, such as in New Jersey and Michigan, might find it advantageous to plant solid blocks of one variety, providing the decrease in set and size of fruit did not greatly reduce yield and grade of berries. Large blocks of a single variety simplify cultural operations somewhat, especially harvesting. However, more than one variety, probably three or four, should be planted to extend the harvesting season and distribute any risks that might be involved in planting only one variety.

PREPARING BLUEBERRY LAND. A good method in New Jersey[10] is to install the chief drainage ditches and burn the undergrowth in a dry period. Then the trees and stumps can be removed most efficiently. A heavy tractor will uproot most of the trees found on such land. Plowing should be deep enough to go through the peat and bring some sand to the top. If the land is kept fallow for a year before planting many of the injurious grubs will leave the site, certain weeds are kept under control, and the coarse roots and sticks will start to decay.

Most New Jersey fields have "thin" spots where the land is a few inches higher than the rest of the field and the peat deposit is very shallow. These spots can be improved by broadcasting peat three inches thick before plowing or placing it in two deep furrows alongside the row of plants. If set without the peat, the plants will grow poorly and the spot will

become poorer and poorer every year. It is difficult to add peat after most of the field is full grown.

All low spots where water stands for any length of time should be drained. Tile can be used to advantage. The main outlets should be sufficient to remove the runoff of the greatest rain in 12 hours. Young plants may start well on poorly drained land and die later, but usually they do not grow at all. Replants usually do poorly because of shade from the neighboring bushes.

SPACING. Most of the first fields in New Jersey were planted 4×8 feet but now 5×9 is preferred, as the bushes grow larger than was anticipated and fruit does not develop abundantly in the shade which results from crowding.

WHEN TO PLANT. In New Jersey some early-fall planting is done; in eastern North Carolina planting is done in late fall or winter. In more northern regions early spring planting is most dependable.

TILLAGE

The blueberry is very shallow-rooted; therefore cultivation should be shallow. Clean cultivation has been the usual practice, but because of danger of erosion and of soil impoverishment it is not advisable as a permanent practice. In Michigan, as soon as the harvest is over, a cover crop of an annual such as oats, Sudan grass, or mixtures of these or other suitable crops should be sown, unless an adequate weed cover crop can be obtained.

Tillage close to the plant by means of ordinary cultivators is impractical after the first two years because of the low spread of the branches of the blueberry bushes. Hand hoeing is an expensive, major operation if weed control is maintained in conjunction with the use of tools that cannot be run close to the crowns of the bushes. The spread of the tops also creates the need for a tool of light draft that can be drawn by one horse or a garden tractor. Root pruning by deep cultivation checks the development of the plants. Shallow cultivation helps to conserve the organic matter in the soil as compared with deep cultivation. The practice of mounding presents the need for a tool that will adjust itself to varying combinations of sloping and flat surfaces. A harrow which meets with these particular requirements has been developed in New Jersey.[196]

Fertilizer for Highbush Blueberries

Stable manure should not be used except as careful trials have shown it safe to use. It has often been very injurious, but light applications to some of the more acid soils are beneficial.

In Michigan the use of superphosphate alone up to 670 pounds per acre has given good results, but about 500 pounds of a complete fertilizer has generally been somewhat better. In localities where blueberries are now planted in New Jersey and North Carolina nitrogen is often the limiting element. For locations where satisfactory practices are still unknown it is suggested that one application, 400–600 pounds per acre, of a complete fertilizer (e.g., 5-10-5) be made in the spring at the time the buds are starting. This should be followed about six weeks later, if the soil is very acid (below pH 4.8), by an application of 150 pounds of nitrate of soda or of calcium nitrate per acre; or, if the soil is not very acid (above pH 4.8), by an equivalent amount of nitrogen in the form of sulfate of ammonia, followed by one or two similar applications at intervals of six weeks. The more fertile fields do not need the later applications. The fertilizer is broadcast to within 6–12 inches of the plant and out as far as the roots extend.

If the foliage shows chlorosis or yellowing, ammonium sulfate should be used instead of nitrate of soda as a source of nitrogen; the plants may then turn green within a few weeks. For blueberries on loam, sulfur may be used in place of sulfate of ammonia. A lack of available iron is a common cause of chlorosis.

Irrigation and Drainage

As the highbush blueberry is a native of swamp and moist lands where the soil moisture is ample throughout the season, cultivated fields also need ample moisture; but, they must be well drained with the watertable 14–18 inches below the surface. However, in periods of low rainfall the watertable may drop so low that the plants and crop suffer severely. Soil-moisture conditions should be carefully considered before planting.

Blueberry fields in New Jersey usually are wet in the spring, and freedom from rain in May favors a strong early growth. Sufficient moisture during June and July is very important in building up the ripening crop. Dry weather for three weeks or more in August or September may decrease the crop the next year.

Because of severe droughts in North Carolina, much of the acreage there is irrigated, part with gravity flow and part with a sprinkling system. Owing to the relatively long season of ripening of the blueberry two or three applications of one- to two-acre inches of water about 10 days apart while picking may be needed. Fields there may also need some irrigation later, during the hot weather of summer.

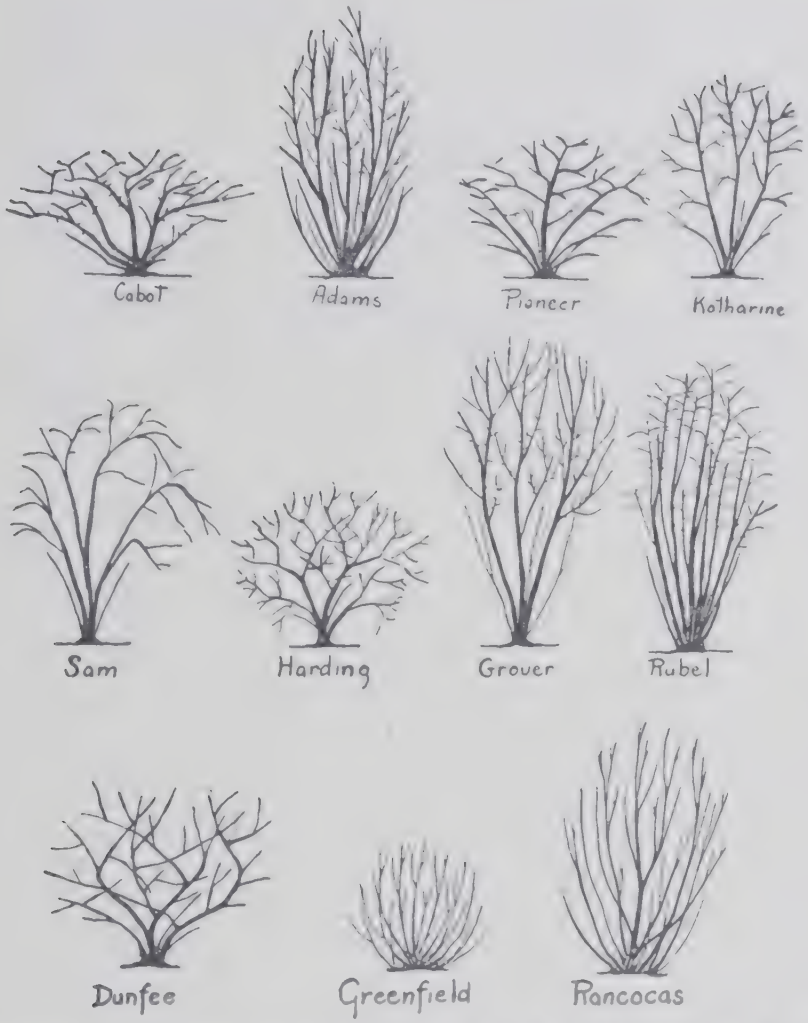
Where soil and other conditions are favorable and a blueberry field can be expected to receive some spring or sidehill seepage water almost continuously, it is often possible to construct the drainage so that the watertable can be maintained practically continuously at the desired level. Under ideal conditions excess water can be quickly removed during or after storm periods and yet the watertable can be maintained at the desired level; relatively inexpensive structures can insure both good drainage and effective irrigation at small cost.

Mulching Highbush Blueberries

Mulching with leaves, sawdust, hay, or straw is used commercially in some areas in New England, New Jersey, North Carolina, and northern Georgia. Mulching materials applied to the depth of several inches keep down weeds, keep the soil cooler in summer, retain soil moisture, help to control erosion, and, as explained under Bramble Fruits, may increase potassium availability. The plant rows may be covered for 2–2½ feet on each side, or the entire area may be mulched. Leguminous hay mulches (e.g., clover, soybean) have sometimes been injurious and should not be used unless tests have shown no injury over a period of several years. When leaves, sawdust, or straw is used, extra nitrogen must be applied to obtain good growth. Several applications of nitrogen fertilizer may be used on mulched areas at six-week intervals. For small plantings ⅓–½ pound per bush should be scattered over the surface at each application, not closer than 6–8 inches to the base of the plant.

Pruning Highbush Blueberries

A good annual practice, beginning about the fourth year, is as follows: (a) The low spreading branches next to the ground are cut out, leaving only the erect branches or shoots. (b) If the center of the bush is dense, the weak and older branches at the center are cut out. (c) Most small slender branches are removed, leaving the strong branches and shoots.



Typical shapes of blueberry bushes. (Courtesy, C. S. Beckwith, N.J. Agr. Exp. Sta.)

Many of these small branches are thickly set with fruit buds. These weaker branches cause the bush to become too dense, thus making picking difficult and leaving inadequate space for strong new shoots.

The blueberry produces fruit on wood of the previous year's growth. The largest fruit is borne on the most vigorous wood. Most varieties tend to overbear, and unless part of the buds of such varieties are pruned off the berries are relatively small and there is too little vigorous new growth for the next year's crop. The erect-growing sorts such as Rubel, Rancocas, Scammell, June, and Concord, need to be thinned at the center, whereas

Cabot and Pioneer are especially spreading and are likely to need pruning of the lower drooping branches. Rubel, Concord, and Rancocas bushes require much thinning out of the small branches and are, therefore, expensive to prune.

In order to increase the size of berries the fruiting shoots of some varieties should be cut back, the amount depending on the number of fruit buds on such shoots. June, Weymouth, Rancocas, Concord, Stanley, Jersey, and Rubel require very little cutting back, but Cabot, Scammell, and Pioneer should be cut back to about 3–5 fruit buds per shoot. The amount of necessary cutting back varies from year to year, depending on growing conditions. Cutting back is usually done at any time from leaf fall in autumn to the beginning of growth in spring.

Heavy pruning (thinning the small branches, heading back clusters, and cutting out some old stems) reduces the crop greatly and hastens ripening. It should rarely be practiced. Light pruning (thinning some of the small branches and an occasional stem), though it reduces the crop for a given year, increases the size and earliness of the berries and results in more vigorous new growth for the next year's crop than does no pruning. The heavier the pruning the larger the berry size, the earlier the ripening, and the smaller the total crop for that year. Under some conditions where the crop is heavy and no pruning is done, most of the berries may not mature. In some cases it is possible to shift the ripening period by the amount of pruning done. In North Carolina and other southern states relatively heavy pruning may be practiced to obtain an early maturing crop, and in the northern states the practice of light pruning may spread the ripening season over several weeks.

In Michigan,[278] late-maturing berries, even though medium-to-small in size, bring better prices than larger, earlier maturing berries. This is because of less competition from wild blueberries, the bulk of which matures earlier than the cultivated, and from other fruits of the same season, such as strawberries, raspberries, and cherries. Therefore, a light pruning which will produce maximum yields of later maturing berries, even though somewhat small, seems best. In light pruning, the aims are these: (1) To remove dead and broken branches and, with a few cuts, the large clusters of very thin, bushy wood that accumulates in mature bushes. It is too laborious to thin shoots individually, and a certain proportion of this type of wood should be left in the bush to produce the

Harvesting scene in a cultivated blueberry field. (Courtesy, Miss Elizabeth C. White, Joseph J. White, Inc., Whitesbog, N. J.)

later maturing berries. (2) To remove an occasional old stem (sometimes called cane) which has lost its vigor and no longer produces any moderately vigorous new shoots. Sometimes it is necessary to remove the entire stem to the ground, but more often it is cut back to vigorous side shoots. (3) To remove bearing branches close to the ground, and so avoid dirty berries. (4) To serve as insurance against extremely dry years when berries on unpruned bushes become very small.

Harvesting and Marketing

The first highbush blueberries from the early varieties are picked about May 20 in North Carolina, June 20 in New Jersey, and July 10 in southern Michigan. From three to seven pickings are made at five- to seven-day intervals. Too many underripe berries are picked if it is done oftener than that. Picking about once a week is usually often enough, because blueberries hang on the bushes exceptionally well after maturity. In any one locality the season usually lasts 6–7 weeks. In eight hours, pickers can harvest 60–80 pints or even more where the crop is heavy. Pint baskets are mostly used as containers, but these must be tighter than for larger fruits such as strawberries.

Full production is reached in 6–10 years, sometimes earlier. Individual bushes should produce a little fruit after being planted one year. When

mature, they usually bear 6–8 pints per plant, and with medium pruning they may produce 12–20 pints per plant. An estimate for good plantings from the second to the sixth year is about 50, 200, 2,000, 4,000, and 6,000 pints per acre, respectively, and larger yields are possible.

In Michigan, the berries are picked into small pails fastened around the picker's waist; in New Jersey picking directly into the cups or boxes is preferred. The former method has the advantages of inspecting the berries as they are poured from the pail into the cups and of removing cull berries, leaves, sticks, and other foreign material. Picking directly into the cups which will be sent to market leaves more of the natural bloom on the berries. Each picker may have a carrier, e.g., which holds eight pint cups.

Grading, when practiced, is done partly by the pickers, who pick only sound berries, and partly in the packing shed, where the baskets are sorted according to the size of berries they contain. A large part of the cultivated blueberries produced in the eastern United States is marketed through a cooperative organization of the commercial growers. In grading, the berries are not actually run over a machine but are graded by means of occasional measuring cup counts. With a little practice, one can place berries in the proper grade at a glance. The cups or boxes are filled rounding full and then covered with a sheet of cellophane which is fitted tightly around the box and held in place by means of a rubber band or piece of sticker tape.

Since the sale of cultivated blueberries at good prices depends on their attractiveness, they must be picked carefully. They must be neither too green nor too ripe. The stem end of ripe berries is a dark, rich blue color. Underripe fruit is sour and lacks blueberry flavor.

CONTROLLING BLUEBERRY INSECTS AND DISEASES

Symptoms of *stunt*, a virus disease, are dwarf bushes, and small, yellow leaves in summer, followed by a brilliant red in late summer and early fall. The berries are small, unpleasant in taste, and stick tightly to the stem. Infected bushes should be removed.

In *mummy berry*, wilting and killing of the shoot tips and blossoms are first noticed in moist weather in early spring; the visible effect is not unlike frost injury. The wilted tips and blighted blossoms produce spores, which later infect the very young fruits. The infected fruits develop to almost full size before their growth is stopped. While normal berries are green,

the infected ones turn cream or tan and shatter easily. Control consists in sweeping or raking the soil surface under the bushes and frequent tillage between the rows during early spring when the spore-producing structures have started to form and before they have discharged their spores. The object is to disturb the overwintered mummies at a critical period, thus stopping further apothecial development. Application of 150–200 pounds per acre of calcium cyanamid to the soil while sweeping helps make the mummies incapable of producing the spore-producing structures. Spraying with fermate is a promising control.

Phomopsis twig blight often does much damage in areas where water stands for some time during the growing season or after abnormally heavy rain has flooded the planting. The fungus enters the tip of a succulent shoot and progresses rapidly toward the base. The tip wilts and turns dark brown or black within a few days, with a sharp line of demarcation separating it from the healthy, light-green bark below. However, some leaves may drop from the apparently healthy part of the shoot and, if the shoot is split, a slightly discolored zone of underlying tissue may be seen extending downward several inches beyond the darkened bark area, and even below this zone the pith is brownish and divided transversely into sections. When the fungus reaches the base of a succulent shoot it enters the older wood, in which it progresses much more slowly. As soon as the older wood is girdled, the parts above the girdle die. Dormant pruning should remove all blighted or discolored wood. The prunings should be carefully collected and burned before growth starts. When blighted tips are seen during summer, the new infections can frequently be removed before the fungus reaches the old wood, by cutting the shoot back to a point where the pith appears normal. After a badly infected field has been pruned, a delayed dormant spray of 1–9 lime-sulfur, followed in two or three weeks by 4-4-50 Bordeaux with rosin-fish-oil soap helps to prevent new infections.

Stem canker is often serious in the South. Girdling of the branches and stems is caused by a fungus in the infected bark, and results in the death or weakening of that part of the stem above the cankered areas. Control is to use plants of the more resistant varieties obtained from plantings free of the disease.

Symptoms of *double spot*, which is a serious leaf disease of the cultivated highbush blueberry in the South, are, at first, tan spots surrounded by a

narrow purplish ring, and, after midsummer, some of the spots are greatly enlarged by the formation of a wide light brown band around the central or original brown spot. Control is to spray with 4-4-50 Bordeaux mixture: (a) soon after bloom, (b) immediately after harvest, (c) about a month later.

INSECTS

The presence of a few *blueberry maggot* infested berries may cause an entire shipment to be condemned as unmarketable. The adult resembles a housefly in shape, is about $^{3}/_{16}$ inch long, with a brown face, shining black eyes and body, white on the sides and rear of the thorax, a white band at the rear of each abdominal segment, and a characteristic white patch on the wings. In New Jersey flies emerge from the overwintering puparia chiefly from June 20 to July 5. In Maine they emerge 20 days later. After flying about for 10–12 days, they begin to lay eggs in the ripe or ripening fruit. The eggs hatch in 2–5 days, and the larvae mature in about 20 days, when they enter the ground, pupate, and remain dormant until the next or some subsequent year. The flies can be killed by dusting with derris (5 per cent rotenone), 10–15 pounds to the acre, when they first appear in numbers but before egg laying has started, with a second application 10 days later. If calcium arsenate, six pounds to the acre, is used, an interval of two weeks should follow the last application before the berries are picked. DDT may be the best control.

The moths from overwintering cocoons of the *cranberry fruitworm* fly in from nearby untilled land as early as May 20 in New Jersey. Eggs are laid on the blueberries after this time. A newly hatched worm enters a blueberry at the stem end and eats the seeds and some pulp. Then it leaves this berry and enters another, usually one that touches it in the cluster. It destroys or injures one or two berries in the cluster before attaining full size. The smaller berries dry up, but some of the larger ones retain their shape and show the injury only by a slight malformation and premature coloring. The early varieties are most seriously injured by this pest. The fruit damage, however, is relatively unimportant as compared with the loss in appearance occasioned by the worms leaving the harvested fruit after it is packed and crawling over the top of berries under the cellophane cover. In New Jersey, pyrethrum dust applied by airplane at the rate of 30 pounds per acre, once at the end of May and again a week later, is

effective in controlling this pest. In Michigan, control is to spray with 3 pounds of Black Leaf 155 and two quarts of summer oil in 100 gallons of water: (a) just before the berries touch in the clusters; and (b) 10 days later if the infestation is heavy. Thorough spraying of the bushes from both sides is essential. DDT is effective in early applications.

When the early leaf and fruit buds of the blueberry start to swell, the beetles of the *cranberry weevil* may bore into some of them from the side and consume most of the contents. Most buds so injured do not open at all, and the few that do form a small rosette of malformed leaves. Egg laying begins when the blossoms show white. A female will puncture the corolla and lay a single egg in a flower, usually among the anthers. The grub hatches in a day or two and eats the stamens, pistil, and part of the ovary, leaving a mere shell. The flower does not open. This pest reduces the crop over 50 per cent in many places. Control consists in repeated dusts or sprays with a stomach poison during the short period between the swelling of the buds and the opening of the flowers.

One of the most obvious leaf-feeding worms is the *datana worm*. It usually feeds in colonies of about 100 individuals, a large enough group to defoliate a bush entirely if not removed. When disturbed, it raises its head and anal segments as though assuming a fighting position. It has a dark head, yellow "neck," and longitudinal yellow stripes which extend along its body. Control is to remove the young colonies by hand. Arsenicals are dangerous to use because of the presence of ripe fruit at the time the insect is feeding.

Other blueberry insect pests are the *blueberry budworm*, *forest tent caterpillar*, *fall webworm*, *leaf rollers*, *blueberry bud mite*, *scale*, *stem gall*, *stem borer*, and *cranberry rootworm*.

6. Cranberry Culture

THE CRANBERRY plant (*Vaccinium macrocarpon*) belongs to the same family (*Ericaceae* or Heath) as the huckleberries, blueberries, and snowberries. It should not be confused with the highbush cranberry (*Viburnum*) which is an ornamental plant and is also used extensively for jelly in parts of Canada, Minnesota, and other northern sections.

The cranberry is a native of bogs of northeastern America, Newfoundland to Minnesota and southward to North Carolina and Arkansas. It is also found in northern regions such as Alberta, Canada. The plant consists of trailing runners with numerous erect branches and roots distributed along it. Both the runner and the uprights bear leaves, but only the latter bears fruit.* Uprights never bloom the first year but normally will the second. The leaves are evergreen but turn brownish in winter. The vines make a mat all over the surface of a cultivated bog. They bloom in late June and early July and the fruit ripens in September and October. The root system differs greatly from that of ordinary farm crops; it consists of a mass of fine, fibrous roots without root hairs. The roots will not grow under water, even though the wild vines grow in bogs or marshes; but they will live under water for months. Because of the lack of root hairs, nutrients must be absorbed by unelongated epidermal cells or must enter those cells through the mycelium with which they are ramified.

Cranberry culture is a highly specialized industry in itself, and there are many important differences between the methods followed in the four chief growing sections (Massachusetts, New Jersey, Wisconsin, and the Pacific Northwest).

* Under western Washington conditions, however, some fruit is borne on the runners, especially with the McFarlin variety in young bogs.

THE CRANBERRY INDUSTRY, REGIONS, AND DISTRICTS

Practically all the world's supply of cranberries is produced in the United States. In Nova Scotia, a maritime province in eastern Canada, there are about 100 acres of cultivated cranberries.

The acreage in Massachusetts is about 14,000 acres, in New Jersey about 12,000 acres, in Wisconsin about 2,500 acres, and in Washington about 750 acres. It would seem right to credit to the industry the land devoted to reservoirs, sand banks, and so forth, for the bogs; this acreage at least equals and possibly exceeds that actually planted to cranberries. With such land included, the total area used for this crop probably would not be less than 70,000 acres. The total value of the crop is about as follows: United States, $6,000,000; Massachusetts, $4,000,000; Wisconsin, $1,000,000; New Jersey, $500,000; Washington, $125,000; and Oregon, $100,000. In 1946, the cranberry industry grossed $20,000,000 from a crop of 850,000 barrels.

MASSACHUSETTS. Cranberries have been cultivated in the Cape Cod section since about 1818, but it was not until about 1850 that the industry became important. In the southeastern section, mostly in Plymouth and Barnstable Counties, the cranberry industry is the chief feature of the agriculture of the region. It has given large value to some 14,000 acres of peat and muck soils which previously had little or no value. It gives annual employment to many hundreds of workers, and it adds several million dollars annually to the value of the agricultural products of the section. The cranberry is the leading export crop of the state. The largest acreages are at Carver, Plymouth, Rochester, and Wareham. Those in Barnstable County are at Brewster, Harwich, and Barnstable. Cultivated bogs are scattered from Marshfield to Provincetown. Massachusetts produces more than half the cranberries grown in the world.

NEW JERSEY. The first plantings were made about 1845. The acreage is mostly in the central Pine Barren region. The chief area is Burlington County, centering at Chatsworth, South Pemberton, Atsion, Upton, Medford, and New Lisbon. There are smaller areas in Ocean, Atlantic, and Cape May Counties. The New Jersey climate promotes weed and fungous troubles more than is the case in other cranberry areas. Many bogs in New Jersey have deteriorated badly owing to false blossom disease, but the acreage at present has not changed greatly from the 12,000 acres of a survey in 1921.

WISCONSIN. The first plantings were made in 1874. The marshes are located near Wisconsin Rapids, Mather, Warrens, Tomah, and Berlin in the central part of the state; near Phillips and Hawkins in the north-central part; and near Spooner in the northwestern part. Wisconsin is well placed in the industry in spite of its troubles with drought, summer frosts, and lack of acidity in many of the marshes; its geographical location gives it an advantage in the delivery of fruit to the markets of the country as a whole; its Searls variety, partly because of the large berries, outyields other cranberry varieties; the crop is harvested more completely and with less injury to the vines than elsewhere by water-scooping (gathered from the water of the partly flooded bogs with long-handled scoops).

OREGON. The first attempt at cultivation of the cranberry in Oregon was made by Chas. Dexter McFarlin, who went to Coos County (a coastal county) and set out vines which he brought from Cape Cod, Massachusetts in 1885. (See McFarlin variety.) In 1911, C. N. Bennett and associates set out the first large bogs in Clatsop County. There are about 35 acres in bearing in Clatsop County, centering at Warrenton; approximately 120 acres in Coos County; and about 15 acres in Curry and Tillamook.

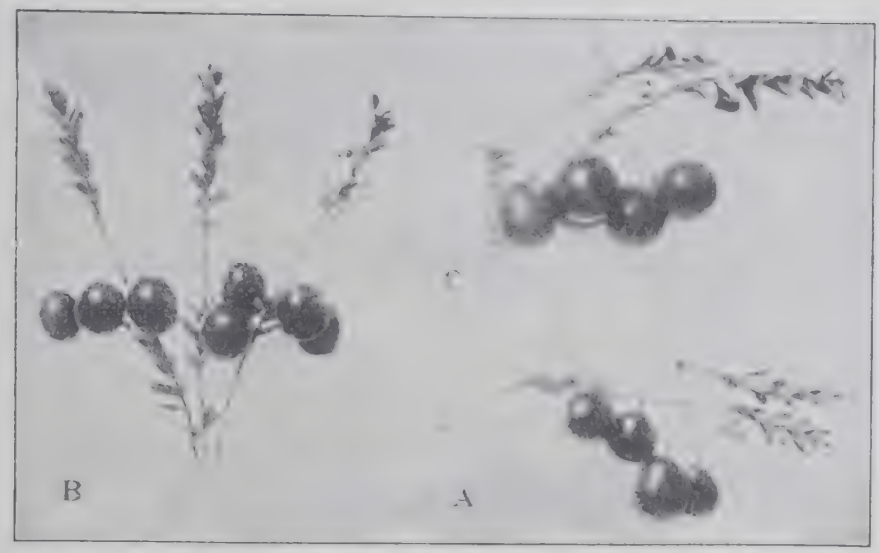
WASHINGTON. The first planting was made in 1881 near Long Beach, in Pacific County, by the Chabot Brothers. In course of time, it was expanded to 40 acres. Little further development occurred until about 1909. From 1909 to 1915 several hundred acres were planted, chiefly near Ilwaco and Long Beach. The vines were obtained from Cape Cod, Mass. The present acreage in Pacific County is about 600 acres; and in Grays Harbor, about 150 acres.

CHARACTERISTICS OF CRANBERRY VARIETIES

Approximately half the crop of Massachusetts is Early Black and one third Howes. In New Jersey, native "Jerseys" comprise 50 per cent, Howes 20 per cent, and Early Black 15 per cent of the total acreage. In Wisconsin, about half the acreage is "natives," 17 per cent McFarlin, 15 per cent Searls, and 5 per cent Bennett. In Washington and Oregon, the McFarlin is the leader.

Varieties with fine vines, short upright branches, low seed counts, and without noticeable bloom on the fruit are generally superior in yield and disease resistance.

In Massachusetts the earliest varieties usually become well colored the first week in September and the latest the third week in October. Some



Sprays of cranberry varieties. (A) Early Black. (B) Howes. (C) McFarlin. (Courtesy, H. J. Franklin, Massachusetts Cranberry Station.)

berries color well in storage; others will not redden much unless left on the vines. Most cranberries are first green, then whitish, then pink, then light red, and finally dark red. Some of the wild berries are white when ripe, and some cultivated ones get so red that they are almost black. The different kinds of berries vary in form, e.g., pear-shaped, fusiform, oval, or round. The round berries are most easily sorted.

No flooding area should have more than one variety. Some leading varieties suffer especially badly from insect or disease troubles, and the planting of other varieties on the same flooding area complicates control.

HOWES (Howe, Late Howes). It supplies the late market, including Thanksgiving, almost exclusively. Berry dark shiny red when mature, oval, firm, very high pectin content. From 90–140 berries fill an ordinary cup.[7] Ripens late, and so interferes with proper fall flooding. Excellent keeper. Susceptibility to false blossom disease is limiting its planting. An excellent scooper. Origin taken from the wild by Eli Howes, East Dennis, Mass., about 1843.

EARLY BLACK. The chief early sort in the East. Berry bell-shaped, very dark red, good quality. From 90–130 berries fill a cup. Makes a fine sauce and outstanding for canning. Vine grows rapidly. Resistant to fungous diseases. More resistant than Howes to false blossom. First planted by Capt. Cyrus Cahoon, Harwich, Mass., about 1859.

"JERSEYS." The name is given to those cultivated cranberries that are simply taken from the wild in New Jersey without any selection and planted in bogs. There is no uniformity or constancy of characteristics in this so-called variety.

CENTENNIAL. Berry cherry-shaped, medium red, extra fine flavor. From 55–95 berries fill a cup, this being one of the largest cranberry varieties. Keeping quality

only fair. Very susceptible to false blossom. Origin—first transplanted from the wild in Holliston, Mass., by Geo. Batchelder, in 1876.

CHAMPION. Berry oblong-shaped, bright red, excellent flavor. From 80-100 berries fill a cup. Only a fair shipper. Subject to fungous diseases and false blossom. Origin—selected from the wild by E. W. Shaw and planted at Carver Center, Mass.

MCFARLIN. The chief variety in Wisconsin, Washington, and Oregon. Keeping quality of berries very good. Resistant to false blossom. Forms many runners, is not well adapted to scooping, and the berry has a slight pubescence or bloom which makes it less attractive in color than some other varieties. Developed at South Carver, Mass., by C. D. McFarlin and T. McFarlin.

SEARLS (Searl's Jumbo). Highly productive in Wisconsin. Large, oval, dark, midseason; keeping quality only fair. Has not succeeded in the East because of the rotting of its fruit. Origin—taken from the wild, near Wisconsin Rapids, by Andrew Searls.

BENNETT (Bennett's Jumbo). Late, oval, good keeper; subject to false blossom. First vines came from Berlin, Wis.; first planted at Fremont, Wis.

"NATIVES." In Wisconsin, vines and berries of this group are referred to by the growers as "natives." Because these vines have been selected to some extent and bear berries of bell and cherry shapes, they are sometimes known as "Bell and Cherry," and other mixed selections are designated "Bell and Bugle," or "Berlins."[169] They are sold, as are most varieties, under brand names of the organization or individual selling them.

DURATION OF CRANBERRY BOGS,* YIELDS, AND COSTS

A properly constructed cranberry bog should bear for 60 years or more. Since the cost of replanting and again bringing a bog into bearing is $500 or more per acre, it is too great to make the practice common. Occasionally it is done, because of serious insect or disease troubles, winterkilling, or unprofitable varieties.

The average yield of bearing bogs is slightly over 20 barrels per acre, including many poorly kept or managed ones. Yields of 100 barrels per acre are sometimes secured, and even much higher yields have been reported. Very few bogs, however, average over 65 barrels per acre year after year. Ordinarily, 5 to 15 per cent and sometimes even 30 per cent of the crop is left by the pickers. Losses also occur from natural shrinkage, due chiefly to respiration, decay, freezing, smothering, and other causes. A yield of 35 barrels per acre may be considered an average crop for a properly located, well managed bog. Growers should not be satisfied with an average yield of less than 30 barrels and should study their conditions if yields fall below this figure.

* Usually called marsh in Wisconsin.

The costs of building a cranberry bog or bringing it into bearing vary greatly. They depend mainly on the natural conditions, make-up and location of the swamp, and on the ability and knowledge of the man who oversees the work. Some estimates have been made per acre, as follows: Massachusetts[213]—cost for land, $10–100; clearing, ditching, turfing, grading, and sanding, $300–600; seven barrels of vines at $3 per barrel, $21; setting out vines, $20–25; incidentals (tools, dams, headgates, buildings, etc.), $200–300; total, $551–1,046. Oregon—clearing and stumping, $100–150; scalping and leveling, $250–300; sanding, $150–200; ditching and diking, $125–150; plants and planting, $50–100; weeding, $125–500; buildings, pumping plant, and equipment, $200–300; total, $1,300–1,700. Wisconsin—Clearing land, $5–75; scalping, picking up, and constructing dams, $35–75; ditching, $15–30; flumes, $7–20 for material and $5–15 for labor; sanding, three inches deep ($0.12½ per cubic yard), $50–100; vines, $65–250; planting, $15–30; total $197–595.

Some idea of the cost of harvesting, handling, and of gross returns is provided by these estimates:[214] Picking 70¢ per barrel; screening, storing, packing, and selling, $1.70; quarter-barrel boxes for packing, 14¢ each. Thus, the harvesting, packing, and selling costs on these estimates were $2.82 per barrel. The average selling price for a period of years was $8.71. This amount, less the harvesting and selling costs of $2.82, gives $5.89 as the gross return per barrel to the grower, or about $200 per acre for a 35-barrel crop, out of which he must pay the interest on the investment, taxes, and the upkeep and maintenance of the bog.

PROPAGATION OF CRANBERRIES

Cranberries are propagated by cuttings or pieces of vines. The cuttings should be obtained from young bogs where the plants are vigorous, free from serious diseases and insects, and uniform as to variety. In securing cuttings, the practice is to mow the vines in the spring (before the terminal bud grows*). The amount obtained is about a barrel of cuttings per square rod or about four tons per acre.

* The first swelling of a terminal bud is sometimes referred to as "opening," but this term is somewhat misleading. The terminal fruit bud develops into an upright, with the blossoms placed near its base, below the new leaves; this upright may, in turn, bear a fruit bud at its tip in the fall. Fruit buds start growth in the spring with or slightly after purely vegetative growth.

Bogs from which vines are cut recover much faster if the cuttings are taken before growth starts. Experienced growers often refuse to cut vines for sale after the new growth appears. If the cuttings have a lot of new growth, much of it is likely to die and further growth will be slow for a time if it does. One who buys such vines cheats himself by paying for much unnecessary bulk.

The amount of cuttings needed to set an acre varies greatly, and the practice is not standardized. At a good spacing of 9-12 × 9-12 inches it takes 7–12 barrels of cuttings to plant an acre, according to the conditions of the cuttings and the efficiency of the setters. At a certain court proceeding,[37] an experienced grower testified that he used 20 barrels of cranberry vines to the acre; whereas another said six were sufficient. There is a difference for varieties; for example, when set 16 × 16 inches, six barrels of Early Black are enough for an acre; whereas seven barrels of Howes are required. The growth of Howes is coarse, tall, and vigorous; Early Black grows rapidly enough, but the vines are finer, the leaves smaller, and the uprights shorter (this helps explain the difference in amount of the two varieties required for planting). As high as $1\frac{1}{2}$ tons (about 60 barrels) are used per acre in the Wisconsin method of planting.

ESTABLISHMENT OF CRANBERRY BOGS

Requirements of Cranberry Growing

Points which should be considered before undertaking to develop a bog are:[169]

(a) Considerable capital is required to develop a cranberry property. The cost may be $500, perhaps $1,500, an acre up to the time of bearing.

(b) This fruit requires an acid soil of peat, muck, or gray sand. Neither alkaline peat nor ordinary farm and garden soils will grow cranberries well.

(c) A constant and ample water supply is needed for irrigation during droughts and for flooding to protect the plants against winter injury, untimely frosts, and injurious insects.

(d) It must be possible to drain the swamp at least 15 inches deep.

(e) The bog should be near a supply of sand.

(f) A climate with moderately cool summers is necessary. The New Jersey and Massachusetts districts are near the coast and with fairly cool

summers; the Wisconsin region is farther north. The industry would hardly succeed where summers are much warmer than in New Jersey. In that state, the berries often rot on the vines, and the prevalence of diseases necessitates much more spraying or dusting than in other commercial sections. Diseases probably would be even more serious farther south, and the high temperatures during harvesting and after picking would shorten the life of the berries and increase the difficulty of marketing.

(g) The summer temperatures must not be so low as to retard blossoming, the development of the berries, or the growth of the vines. The shortness of the growing season and the coolness of the summers may prevent the extension of the industry much farther north than Nova Scotia. In some seasons cool, cloudy weather lengthens the bloom period in Oregon and Washington, so that the berries mature very unevenly.

(h) The present centers of the industry are probably among the most favorable sections for cranberry development. To develop new sections requires years of work in selecting varieties, learning the business, and training adequate help.

(i) Experience is a very important factor in this industry, and to acquire it is a matter of years. Acquaintance with ordinary lines of farming is of little value, since, to succeed, one must become expert in controlling the insects and diseases affecting the vine and fruit, in handling water for irrigation and flooding, in frost forecasting, and in the general management of a cranberry bog or marsh.

Soil and Indicator Plants for Cranberries

Conditions which closely approach those where cranberries grow wild are basic requirements in many respects. Cranberries in cultivation, as in the wild, do best on swamp land of muck or peat; depth of this soil need not be great, a few inches of peat or a layer of turf or clay often giving excellent results. It does not appear that any peat is essential, for vines grown on sand alone (so-called "hard bottom") often produce fair crops when fertilized. The soil must be acid.

The following types of swamps, in order of their importance, are most used for cranberry bogs:[169] leatherleaf, sphagnum, and heath; white cedar; red maple; mixed trees; grassed swamps ("fresh" meadow and swales); gray sands (savannahs); and pond bottoms.

Some factors are common on most land suited for cranberry culture in

New Jersey.[37] The top layer is an acid peat or muck, which varies in thickness from a part of an inch up to 20 feet. Under this layer there is one of sand which may vary in thickness. The sand is underlaid with a "hardpan" which is impervious to water. When the upper or muck layer is very thin, it may break up so that the sand looks blackish or grayish, and is known in New Jersey as savannah land and on Cape Cod as gray sand bottom.

Savannah soil in New Jersey usually lies between the true upland and the muck soil and it varies with the muck content. On such soil the ordinary vegetation is leatherleaf ("brown bush") and sphagnum moss; also, the wild cranberry, swamp maple, sweet pepperbush, huckleberry, sheep laurel, and green brier. There is more or less savannah soil along the margins of the New Jersey bogs, but, besides that, there are many pond-like spots here and there throughout the pines and many large open swamps which are mostly savannah soil. These savannahs are covered with water in winter, and in summer they dry out to some extent but are seldom entirely dry. The larger swamps are fed by a runlet and the small streams by rainfall. Usually, the cranberry soil along the streams in the south Jersey pine region is only a narrow ribbon but sometimes it makes a swamp several hundred yards wide. The surface of the ground is usually covered with sphagnum moss and many of these plants are present; pitcher plant, cinnamon fern, royal fern, wintergreen, and sundews. The soils sometimes have a muck layer 25 feet thick, but on the usual bog it is less than five feet thick. Throughout the muck soil can be found logs and stumps.

Soils upon which successful bogs are growing vary from pH 3.2 to 4.5. A soil predominately of brown sphagnum peat is better under Washington conditions than is one of decomposed leaves, grasses, sedges, decaying wood, or one of heavy black muck. Among the common plants found on land adapted to cranberries in Washington[149] are: buckbrush, *Ledum columbianum*, Labrador tea, alder, spruce, sweet gale, salmonberry, and wild cranberry; also, swamp grasses, rushes, sedges, ferns, and sphagnum moss or peat are found in practically all the local peat bogs. Land where horsetail rush or yellow weed occur should be avoided as these weeds are very difficult to eradicate.

Fresh meadow and freshened salt marsh sometimes are made into cranberry bogs without turfing, the grass being laid down and covered with about five inches of sand and the vines set out without other preparation except grading and ditching. Swales and pond bottoms may be used

Such bogs are built cheaply and usually do well. Brush swamps are preferable to wooded ones, for it costs less to clear them. If timberland is used, the tree stumps must be pulled or dug out, e.g., by a winch and hoist, and taken from the bog. Dynamite is often used to blow out stubborn stumps, but filling the holes made in soft land is costly. Much labor may have been wasted on removing stumps, for on old bogs the vines are commonly more thrifty and productive over buried stumps than on areas between them. It may be best, therefore, to cut down the tops of stumps which are hard to remove and cover them over.

Classification of Bogs

Cranberry bogs in Massachusetts are classified[2] as dry bogs, bogs with winter flowage, bogs with winter flowage and one spring flowage, and bogs with full flowage protection. A dry bog is one not covered by water at any season of the year. A bog with winter flowage is one covered by water during the winter. The water may be flowed on by pumping or by gravity from a reservoir, pond, lake, or stream, or may be supplied by snow and rain. Bogs with winter flowage and one or two spring flowages are protected not only against winterkilling but also largely against spring frosts.* Bogs with full flowage protection are those with sufficient water to overflow the bog in winter and to protect the vines from spring frosts and insect pests, and the berries from fall frosts. Bogs with such flowage protection are located near a stream, pond, lake, or reservoir from which water may be flowed by gravity or pumped upon the bog. It is equally important to be able to drain the excess water quickly from the bog.

Of the total cranberry bog acreage in Barnstable County 2.3 per cent has had winter flowage and one spring flowage; 0.5 per cent, winter flowage and two spring flowages; and 24.9 per cent, full flowage protection. Only one fourth of the Barnstable County bog acreage has had as much protection as needed in times of frosts in spring and fall. In Plymouth County, 6.3 per cent of the bog acreage is dry; 28.0 per cent with winter flowage only; 8.5 per cent with winter flowage and one spring flowage; 2.2 per cent with winter flowage and two spring flowages; and

* Spring frosts which cause crop failures are much more likely to come long before bloom than at bloom. In Wisconsin, a marsh with only two flowages would be practically worthless.

55.5 per cent with full flowage protection. About three fourths of the bog acreage with full flowage protection is in Plymouth County. Such bogs may generally be protected from the most serious frosts and are those upon which growers must depend for crops in a year when low temperatures in September might freeze a large percentage of the berries. There are dry bogs which, because of a favorable situation, are not subject to much frost damage. These are rare and exist under most favorable conditions of location and atmospheric movements. Other than the bogs with full flowage protection there are several thousand acres of bogs in Massachusetts with very little protection, other than favorable location, against the frosts of spring and harvest time. These bogs are largely responsible for much of the variation in size of crop from year to year.

Form and Size of Bog

Other things being equal, small bogs pay much better than large ones in Massachusetts.[213] Long narrow bogs, after a certain size is reached, are more profitable than compact ones. The care of large, compact bogs and the harvesting of their crops are relatively costly, as it takes longer to wheel sand to the center of the bog and to bring the berries from the center; also, most bog operations call for more tramping over, and consequent injury to, the vines on large blocky areas. But, perhaps the greatest drawback to the large bog is the fact that the blackhead fireworm is generally more prevalent on such areas. Flooding favors this insect by destroying a fungus that often attacks it severely and by killing or driving from the bog most of its enemies, such as spiders and parasites. The natural foes of the pest are slower in again reaching the center of a large, compact bog in effective numbers than they are in reaching the center of a small one. If, however, a large bog is long and narrow, none of the factors mentioned are unfavorable.

The cultivated Massachusetts bogs[455] range in size from several rods to 235 acres. Bogs of 20 acres or less are usually more profitable than larger ones if they have satisfactory flowage facilities. Some bogs that are a unit in formation are divided into sections as to ownership and operation. The ownership of much of the bog acreage in Massachusetts is concentrated in relatively few hands.

In Wisconsin, the marshes are subdivided into small sections, usually rectangular in shape and placed symmetrically one to another. Roadways

on a sufficient number of dikes make all parts of the area reasonably accessible. In insect control, each small section can be handled as a separate marsh. There seems to be no tendency in Wisconsin for the blackhead, or any other insect, to vary in relation to the size of the marsh.

Location of Bogs and Water-supply Systems

A cranberry bog should be on or near a stream large enough to flood it at any time. If the stream is too small, its capacity for flooding must be increased by making a reservoir above the bog location.

A water supply for flooding as much as may be necessary at any time, especially for flooding by gravity, adds greatly to the value of a cranberry property. It is often difficult and costly to arrange for such a water supply in developing a new bog. In Massachusetts there are special laws favorable to cranberry growers in this connection. The water of state ponds is often used, under the direction of the Department of Public Works.

Pumping versus Flooding by Gravity

Many bogs are flooded by pumping from ponds, lakes, reservoirs, or streams at lower levels; a third of the acreage in Massachusetts is treated in this way. The service of reservoirs is often greatly extended by pumping the water used in flooding back into them again and again.

The pumping plants in use range in lift from 1–24 feet, averaging nearly six feet. Their horse power averages about 30 and their capacity probably about 6,000 gallons a minute. A pump delivering 10,000 gallons a minute will flood 14 acres in 10 hours if the bog is not over a foot out of level.

Flooding by gravity is often a satisfactory arrangement. But, all things considered, it is doubtful whether this method is usually the cheapest and most satisfactory.* Bogs which must be flooded by pumping are generally so much better drained than those which are flooded by gravity that they are much less weedy and therefore less costly to take care of, and on the average they also yield more than bogs that are flooded by gravity. These important items give the bog which is flooded by pumping a perhaps

* Wisconsin growers seem to feel greater security with a gravity feed system "necessitating a perfectly operating plant". With the present dependability of pumps there would seem no reason why the growers should continue to shun pumping locations, but they do.

unexpected value and standing. On the whole, therefore, flooding by pumping is fully as satisfactory as flooding by gravity, and bogs flooded by pumping are more profitable.

Drainage

A bog should be well drained during the growing season. Poor drainage favors weed growth and the rose-bloom disease and probably promotes infestations of the black-headed fireworm and diseases which cause berries to rot both on the bog and in storage. It also curtails the growth of cranberry roots. The land below the bog should slope rapidly, so that the water may be drawn from the ditches at any time.

A ditch, three feet wide and two feet deep, should be cut entirely around the bog and other ditches dug across it, dividing it into sections. The marginal ditch prevents upland growths from working onto the bog, keeps many crawling insects off, and is some protection from forest fires.

If the drainage from the bog is good, the cross ditches are not important unless the area is large or the bottom close or springy. They hasten the distribution of water over the entire area in frost flooding and irrigating. Without them the water tends to pile up for a time at the end of the bog where it is admitted. They usually should be 100 feet or more apart, and are made about two feet wide at the top, one foot wide at the bottom, and 18 inches deep. One of them should be wider than the others and run lengthwise of the bog, in the path of the direct flow from the water supply to the outlet, to hasten flooding and draining. No more ditches should be made than are necessary because they interfere with bog operations. Tile drains are useful if the bog is hard to drain.

Grading

The soil thrown out in ditching may be used in grading. The grading is done by the water line in the ditches. All bogs should be made level, so that they may be flooded quickly and with little water, and no swamp that cannot be so graded with moderate expense should be used unless the water supply is very ample. If the swamp is large and much out of level, it is often best to divide it with dams into separate areas, each nearly level, at different elevations according to the lay of the land. This greatly reduces the water required for flooding.

In building a bog the deeper any cranberry flood is, the more it harms the vines.

"Turfing" or "Scalping"

After the land has been cleared of trees and brush, and ditched and drained, it is "turfed" or "scalped." The turf is cut in squares of handy size with turf axes and these are turned upside down with turf hooks and allowed to dry. They are then broken up easily with a grading hoe and all pieces of roots found in them are burned. Care must be taken at this time to remove from the soil the roots of ferns and of all plants likely to give trouble later. All work on the land up to sanding should be completed late in the summer or in the fall.

Dams or "Dikes"

The objects are to hold the water in reservoirs, maintain the summer and winter floods, and separate a large field into sections to facilitate flooding and other operations.

Large swamps should be divided into several flooding areas. Small areas can be flooded and drained more quickly than large ones, and the water usually can be maintained at a more uniform height. When large bogs are flooded, winds may cause the water to wash the dikes badly. For convenience in applying water, a flooding section in Wisconsin should not contain more than four acres and in New Jersey not more than 15. In Massachusetts some sections contain 100 acres, but those of 15 acres or less are relatively more profitable.

After clearing, a trench about two feet wide is dug along the center line of the embankment for its entire length. Sand is placed in the trench and above it (sufficient to impound up to five feet of water) to form the body of the dam. The dam is made about 12 feet wide at the top (sufficient for a safe roadway) and sloping, at about 60°, to a wider base. The slopes are protected by turf cuttings carefully placed by hand in single horizontal layers, so that the covering is about 1½ feet thick. These turf facings are given weight and substance by placing sand between the turf layers.*

In order to compact the material firmly, water should be raised to a "full head" and then allowed to recede slowly.

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* Rightly or wrongly, the dams are not built as carefully in Wisconsin as in the East.

In large reservoirs or bogs, waves of considerable force may be kicked up by a swift wind and damage the dam. One method of providing protection is to drive light piles at intervals just above the foot of the slope and pack brush in between the piles and the slope. Another method is to use rough slabs driven close together flat against the surface of the dam. These slabs take the force of the waves and retain any material that may be loosened from the slope of the dam. Stone riprapping is also often used for this. Providing a spillway to carry off excessive flows when the reservoir is full should be part of the design of every dam, especially those of lightly compacted earthwork.

Gates or "Flumes"

Gates are made to regulate the flow of water through the dikes. They are of two distinct classes, the open-flume and closed-trunk. All gates must be provided with cut-off walls or sheet piling to prevent the water from leaking through the embankment of the sides of the gate and eventually washing it out. It is wise to build the principal head-gates of concrete if this can be done on firm ground; for all other situations, it is more practical to build the gates of treated lumber and replace them when necessary than to go to the much greater cost of building concrete gates.

Many of the older gates are the open-flume type, which is well suited to bogs lying across a stream where the gates must accommodate the entire flow of the stream and occasional flood flows. In other types, the trunks are constantly submerged and the sills at receiver and outlet ends are higher than the top deck of the trunk. Thus, the buried portion of the trunk remains full of water regardless of the water level in the ditches.

Brakes or checks for irrigation purposes should be located at intervals in ditches with comparatively steep slopes to hold the water back in the upper reaches and reduce the flow. The checks consist simply of a shallow flume with a short cut-off wall of sheet piling provided with guides for holding boards across the stream.

Sanding

When a layer of sand three inches or more thick is spread over the peat, the benefits are as follows:[69] (a) it makes the property more nearly level by filling up the smaller depressions left in grading; (b) the cost of

weeding is reduced, for weeds grow less rapidly on clean sand than on peat (the lower cost of weeding is especially noticeable during the first two years after planting); (c) vines grow more vigorously on sanded areas, often covering the ground and smothering the weeds in two years (such vines come into bearing earlier than those on unsanded peat); (d) it helps in frost protection. (In Wisconsin, on cool nights in summer the surface sand raises the temperature of the air above the vines higher than that above vines on unsanded peat. Wisconsin growers need such protection even more than those in the other areas, for their region is colder and more often visited by frosts); (e) it helps to control insects, such as the girdler, tipworm, and green spanworm; and (f) sanded areas are capable of better drainage and aeration than those of peat and are less likely to suffer from drought.

In Wisconsin, the sand is commonly spread in winter on the ice. This is also done considerably on Cape Cod, but it is not the usual practice there.

Massachusetts growers usually put a three-inch layer of sand on a cranberry field at the time of construction and apply another layer one-third to one-half inch deep after three years of growth, and so encourage the rooting of runners and a heavy stand of uprights. Vines so treated, being well anchored, are easily picked with a scoop. A three-inch layer of sand requires about 400 cubic yards to the acre. The sanding should be done in April or May, for the vines set easier and grow better if they are put in before the sand packs.

As the cranberry roots form a dense growth in the sand over the peat, they become soil bound, and resanding gives them more soil to grow in. Therefore, resanded vines are generally thriftier and more productive. Moss and fallen cranberry leaves are poor conductors of heat and bogs not resanded regularly are commonly covered with such material and so are very subject to frost injury.

Bogs with little water for reflooding should be resanded every other year or every year lightly; those with plenty of water for frost and insect flooding and with a moderate vine growth should be resanded every third or fourth year; and those with ample water supplies and heavy vines should not be resanded. From $\frac{1}{4}$–1 inch of sand, according to circumstances, is put on at a time, being spread with square-pointed shovels.

Sanding may be done most cheaply in winter with favorable weather,

but there is not enough ice for this on Cape Cod in more than one year in three. Considerable injury is done to the vines by resanding in early spring and it increases rapidly as the season advances.

Setting Cranberry Plants

Planting is done from early April to mid-May. If planted after June 1 the cuttings start poorly and make little growth. They should be set soon after the sand is applied, as they do not start so well if it is allowed to become packed by rain before planting. The cuttings are planted directly in place without previous rooting.

Planting distances vary from 6–18 inches apart each way. In Wisconsin, because of the slower growth due to cooler weather, the spacing is closer than in the East. The closer the vines are set in any region the sooner they cover the ground, the less the necessity for weeding, and usually the sooner a paying crop is secured. Vines that are set close together become well anchored and resist best to pulling of the scoops in picking (see Propagation).

The cuttings commonly are made 5–10 inches long. If many vines are set in a bunch, those in the center die and are wasted; 2–3 to a hill are enough. They must be pushed well into the sand but need not go into the peat beneath, for most of their roots will grow in the sand. A wooden or iron dibble is used to press them in. They need not stick up from the sand more than an inch. The new runner growth which comes from the cuttings will then be close to the ground and the runners will root more readily in the sand. There is also danger of cuttings being whipped loose by wind, or of being dried out if too much is left protruding above the sand. One man can plant about 10 square rods in a day. On muck-bottom land, where the wet soil discourages kneeling, the planters work in pairs. One man drops the vines in place and the other man presses them in with a long-handled dibble and firms the soil around the cutting with his feet.

Cuttings may be made about six inches long, spread broadcast, and covered lightly with sand, but this requires more vines than the former method and there is danger of their becoming less well anchored.

With the "wet" method of management, as in Wisconsin, mowed vines are broadcast on thoroughly soaked raw peat or muck and are shallowly cut into the soft soil by tools devised for the purpose. The watertable is

held high for most of the first year to give the vines a chance to root. The shallow-rooted plants resulting are not adapted to deep drainage. In some cases, light coatings of sand are applied after the ground becomes vined over, but often sand is never added. The chief advantage of this method is its low initial cost.

Care of the Newly Set Bog

The first year the cuttings form roots and a few uprights. The second year a few runners develop. The third year the surface becomes considerably covered with vines, though frequently it is uneven. After the third year, the plants cover the ground more uniformly and their growth overcomes that of some of the grass and weeds which developed at the point where the cuttings were set out. Cranberries require three or four years to come into bearing.

Water should be put on right after planting, held near the surface a day or so to wet the vines and pack the sand around them, and then drained to the bottoms of the ditches. If the bog is flowed again the first year, it should be only for a day or two to wet the sand or control insects.

New bogs should be flooded for the winter as soon as the ground begins to freeze, for frost in the soil heaves new sets out. Surplus water must be let off at times of thaws or heavy rains in winter or early spring, otherwise with the vines frozen into the ice the raising of the ice pulls them out of the ground. The first three years the winter flowage should be let off about May 5 in Massachusetts. Earlier removals expose the plants to possible frost heaving.

More weeds grow on a bog the first few years than later, for the vines have not grown enough to crowd them. They give relatively little trouble afterward if they are kept down then. Eventually, however, many serious weeds are carried on the bog and remain unnoticed in the vines until they have covered considerable areas. It is enough to mow the tops of some kinds (most rushes), and some (rice cut-grass) can be checked by good drainage, but others must be rooted out or killed with salt (ferns, brambles, hardback, leatherleaf, and sheep laurel) or kerosene (grasses and sedges). Upland weeds often appear on new plantings, but, they die in the winter flood. Constant roguing is necessary the first three years to remove plants of odd varieties and hills with false blossom.

The Use of Water

After the first year and before it comes into bearing, the new planting in Massachusetts should be flooded five times each year at 10-day intervals, beginning June 1, to check the fireworm and other pests.[20]* The discussion which follows is a guide to flooding practice after the third or fourth year (when the bog is in full bearing).

The bogs cannot be flooded during bloom without loss of crop. In Massachusetts, the normal time of bloom is June 25 to July 18, but it varies with the year and bog conditions, extending into August if the winter flood is held late. Early Black usually blooms about a week earlier than Howes. The berry matures in 60–90 days.

Winter Flooding

This is ordinarily done early in December in New Jersey and Massachusetts (as soon as the sand surface remains frozen all day), and some time during late October on new plantings and in late November or early December on old ones in Wisconsin. The water should be held just deep enough to cover the vines. The winter flooding is a protection against winterkilling of the vines, but is unnecessary on the Pacific Coast.

If the bog can be reflowed, the winter water should be let off about April 1 two years out of three in Massachusetts. It may be held till May 25 the other years† to control the fruit worm and false armyworm, reduce weeds and fungous diseases and promote vine growth. It must not be held so late if it is deep over much of the area or the vines are over-vigorous. Abnormally warm weather in April and May reduces the crop, probably because of restriction of respiration of the vines and their roots from slow or occasional oxygen starvation under high temperatures with reduced sunlight.

Frost Flooding

To avoid damage from frosts in late spring or early fall, water may be let down from the reservoirs to fill the ditches or be brought up around the vines. The protection, which is substantial, is due to direct radiation of

* There is no necessity for such frequent insect floodings in Wisconsin.

† It probably is better to let the winter flowage off early in April, reflood about April 25, and hold the water till May 25, than to hold the winter water late. This serves all the purposes of late holding, airs the vines, and gives time to work on the bog.

heat from the water to the air because of the high specific heat of water. It usually takes only two or three inches of water under the vines (they are not covered) to achieve almost complete protection. Flooding should not be done during or after bloom, for it will blast the blossoms and promote rapid development of fruit-rot fungi.

In Wisconsin,[22] the vines must be adequately protected against winter and early spring killing throughout the long, severe, cold season. The transition period from winter to summer condition of the marsh is attended by much uncertainty as to the best method of management. Frosts are likely to occur frequently from May, when vine growth usually starts, until late in June, when blossoming begins, occasionally in July and August, and with increasing frequency in September. Any one of them may cause partial to total crop failure.

To assist in the frost control program, the U.S. Weather Bureau provides special frost warnings. These are supplemented by the services of State Cranberry Stations in the chief regions. The water does some harm in either spring or fall. In the fall it tends to impair the keeping quality of the fruit. Therefore, and because unnecessary frost flooding wastes the limited water supplies, accurate forecasts of frosts are very important.

Cranberry winter buds will endure 25° F. until they swell to a diameter of more than two mm. They usually will endure down to 20° till the end of April in Massachusetts. Often 28° is reached in a time of tenderest growth without injury, but in such cases the greatest depression does not last long. Temperatures above 29° do little harm.

Spraying a cranberry bog to control insects and diseases. (Courtesy, H. J. Franklin, Massachusetts Cranberry Station.)

In September and October frost danger often necessitates flowing again for protection, but the berries and vines will endure more frost then, and longer chances may be taken than in spring. In the greenish white stage that precedes ripening, cranberries usually will stand 27° F. without hurt and 26° with little injury, but 25° seems to harm such fruit greatly if it lasts long. Freezing begins among ripe Early Black and Howes berries at or slightly above 22°; no softening follows exposure at 23°. Ripe Howes and McFarlin berries are so resistant that under bog conditions often only 10 per cent freeze at 16° and only 20 per cent freeze at 14°. Sometimes, however, 25 per cent soften at 18°. With Early Black berries the loss at these temperatures is greater.

Flooding for Irrigation

A comparatively small quantity of water, in comparison with that required at other times, sometimes is supplied during dry spells in the summer to keep the vines thrifty and the berries of good size. If the sand is moist within half an inch of the surface, the vines have all the water they need, even though the surface itself is quite dry and the watertable is low. Occasional light flooding for a few hours at night followed by complete withdrawal of the water is perhaps better than holding the ditches full a long time in the growing season.

Watertable studies in New Jersey[38] for a five-year period did not show any great difference in yields when the water was held at various depths, the yields in barrels per acre being 54, 63, 70, and 68 at the surface, 3–6 inch, 6–9 inch, 9–12 inch, and 12–15 inch depths, respectively. This favors holding the water at least six inches below the surface. Water at or near the surface decreases the length of upright shoots, the tallest being on the deepest water-level plot. The number of uprights is correlated with their length, being fewest where the water is near the surface and most numerous where it is 6–12 inches below. The warmer air associated with a lowered watertable is the underlying cause since growth occurs early. There is a need on unsanded bogs to maintain the watertable at one point. If watertables are changed considerably, rot is likely to occur where the water is raised to near the surface, due to disturbing the root system.

In Massachusetts[21,8] the watertable during the growing season should be kept very constantly 10–12 inches below the surface, except after heavy rains when it seems best to drain out the ditches completely for a few days

and then refill them to the 10–12 inch level. Because most bogs are not level, a more extensive use of ditch stop-water is needed.

Flooding for Insect Control

Bogs in Massachusetts used to be flooded regularly early in June to check insect pests. This is advisable one year in three but is a dubious annual practice for it carries fungi to the new growth, promotes fireworm infestation, and may reduce the crop by drowning the flower buds. This flood should go on in the night and also be taken off at night if the weather is very warm, for if tender growing vines stand in water long, exposed to a hot sun, they may scald. The flower buds are less likely to be hurt by the flooding if the weather is clear while the water is on, for light is necessary to the photosynthesis by which the plants give oxygen to the water. Cloudiness with a high water temperature is especially dangerous, for the warmer it is the faster the plants respire and the greater their need of oxygen. The complete flood should not be held on a bog over 30 hours unless the weather is definitely clear and cool and should not be held over 20 hours if the bog has a bad record of injury by June flooding.

As soon as the crop is gathered, the bog is flooded for a week to water the disturbed roots and float off fallen leaves, berries, and other trash. If much of this material lodges on the vines, it is very harmful. This flood also controls the girdler when it is done late in September. No flooding is necessary after this till the water goes on for the winter.

FRUIT-BUD FORMATION, GROWTH, AND FRUITING

In Massachusetts[2,4] flower-bud formation is first evident about August 10. Growth is slow during autumn, ceases during the winter, but proceeds rapidly after the removal of the winter flowage. Late drainage delays the resumption of blossom-bud growth, but the development proceeds thereafter so rapidly that bogs held late are only a few days later than early drained bogs in reaching full bloom. Holding the water probably reduces the number of blooms. The number of aborted blossoms is somewhat higher on late than on early drained bogs. Though late draining reduces the number of blooms, it increases the set, sometimes 10 per cent.

There is a relation between the length of growth made by the uprights and the yield. Large yields are obtained in Wisconsin when the average

growth is $2\frac{1}{2}$ to $3\frac{1}{2}$ inches long. This is the optimum growth for several varieties, though the largest yields occur on McFarlin with somewhat shorter growths than in Howes. The difference in optimum growth for these two varieties is not more than $\frac{1}{4}$ inch. A leading factor affecting growth and maximum yield is the stand of uprights. Optimum growth and maximum yield result when the number of uprights is 200 to 300 per square foot. If any attempt is made to alter or control the amount of growth, it is important to remember that a proper growth of about three inches is made by about the time the blossoms open. Poor crops of fruit on the more vegetative uprights in areas of high stands of uprights are due to both shading and to poor pollination.

The blossoms bend down (forming "hooks"). This habit makes pollination possible. The anthers do not dehisce pollen directly into the air as is common with many species of plants. In the cranberry, the ripe pollen is delivered into long hollow "tubes" attached to the anthers. As the blossom begins to open the pollen is liberated in close proximity to the stigma of the pistil which by then has grown to be equal in length to the anther tubes. The stigma is receptive at this stage of blossom development. Pollination is brought about by wind-borne pollen reaching the pistil. This is not effective any great distance as emasculated blossoms left in the open rarely set fruits. When honey bees visit the blossoms for nectar, they do not usually touch the stigma. The jarring of the blossoms during their visits is of prime importance in any aid to pollination which they render. Cranberry flowers may reach "full blossom" in two hours under favorable weather conditions. Another peculiarity of the cranberry blossoms which aids fruit setting is that the pollen is not a simple grain as is usually the case in plants but is a tetrad capable of germinating into four functional pollen tubes. Also, fruits may set with very few seeds maturing.

FERTILIZER

Nutritional Studies

The nutrition of the cranberry is complicated by the fact that under ordinary cultural conditions the green plant exists in close association with a fungus or endophyte. Though an association of a fungus with the roots of a higher plant is called a mycorrhiza, the literal definition of the

word must be extended somewhat to include the condition that exists in the Ericaceae, for in this family the fungus is not confined to the roots but is coextensive with the growth of the plant, occurring in practically every organ.[2]

In New Jersey:[2] (a) cranberry plants were grown for several months in sand culture supplied with nutrient solutions containing nitrogen as nitrate and ammonium, respectively, and with one lacking nitrogen. All except the minus-nitrogen series produced runner growth exceeding that of similar plants grown in a bog; (b) plants of the ammonium series produced greater runner growth than did those of the nitrate series; (c) low concentrations produced little growth; (d) mycorrhiza was found in the cultures but least in the minus-nitrogen series; (e) the small amount of vegetative growth in the minus-nitrogen series indicated that, if nitrogen fixation by the endophyte occurred, it was inadequate as a source of nitrogen for the cranberry plant; (f) nitrates could not be detected in either cranberry plant or endophyte at any time (thus if nitrates are absorbed as such, they must be converted into other substances immediately); (g) experiments with organic nitrogen disclosed that ammonium nitrogen can be utilized by the cranberry plant.

The above studies indicate that ammonium sulfate in itself is not toxic to cranberry plants, though several field trials in New Jersey[3b, 3m] have indicated that under certain conditions it may not be used successfully as a fertilizer in cranberry bogs.

Further work in New Jersey[3] has indicated that young cranberry plants are capable of utilizing a variety of different substances as sources of nitrogen but that this ability varies with the reaction of the nutrient solution. In sand cultures, nitrates can be used to at least fair advantage in acid but not in alkaline reactions; whereas ammonium can be utilized in neutral or alkaline but not in highly acid reactions. The findings are interesting because cranberries are grown commercially in decidedly acid bog soil and a commonly used nitrogen fertilizer is sodium nitrate. It might be expected that bog soils to which ammonium sulfate is added would be inferior to the nitrate plots. Quite the opposite is true, however, for ammonium cultures, both with and without lime, produce greater stem growth than do nitrate soil cultures. The difference between soil and sand cultures is due to the greater buffer properties of the bog soil.

A commercial grower[3] has stated with respect to ammonium sulfate that at first it produced greater vegetative growth than did either sodium nitrate or dried blood and that the leaves were dark green but that after it had been applied for several years the foliage became noticeably lighter, there was a decrease in yield, and the berries were of poor color and keeping quality. These symptoms are those of an excess of nitrogen, resulting in excessively vigorous vegetative growth and ultimately in a decreased yield. The cranberry is quite sensitive to an oversupply of nitrogen. Not only is ammonium probably a more quickly available form of nitrogen than is nitrate for the cranberry but the amount of nitrogen in a molecule of ammonium sulfate is approximately 25 per cent more than in one of sodium nitrate, necessitating the use of a smaller quantity of the salt as a fertilizer.

No advantage is gained by fertilizing peat-bottom bogs. Nitrate of soda and superphosphate often greatly increase the yield on "hard bottom" areas (sand or clay underneath instead of peat), and 150 pounds of the former and 300 pounds of the latter to an acre is a reasonable application. Mid-June, when the spring frost-flooding is past and the vines are beginning to bloom, is probably the best time to apply fertilizer in Massachusetts.

Nitrate is likely to promote too much vine growth on peat bottom, especially if the bog is new. It is generally better to get more vines, where they are desired, by holding the winter flood late than to fertilize for them.

Fertilizer helps greatly to repair old bogs out of condition from grub injury. Reground nitrate of soda scattered broadcast early in April in Massachusetts, 250 pounds to an acre, reduces haircap moss well and helps the vines compete with it.

PRUNING CRANBERRIES

There is only one condition that justifies ordinary pruning of cranberry vines. If, after picking an area, loose runners are found floating around over the tops of the vines, they should be cut off carefuly with a knife rake so that the work is done without cutting the uprights (flowering branches) also. If, as is sometimes the case, the vines as a whole, including the uprights, are very tall and dense, this excessive growth is undesirable; but the best way to deal with it is to mow it off close to the ground and let it grow.

HARVESTING AND MARKETING CRANBERRIES

Season

In Massachusetts the usual time to begin picking is right after Labor Day (in very early seasons the picking is started late in August; in late seasons, it is delayed until the second week of September). The period continues until about October 20. Because the cranberry area in New Jersey lies to the south of the Cape Cod area of Massachusetts, it might be thought that picking would be started earlier in New Jersey. However, cranberries are marketed from Cape Cod as early as from any other region. The acreage of early varieties is larger in Massachusetts than in New Jersey and, in the latter region, the winter flood is usually held later (thus delaying maturity). In Wisconsin, the season is from the first week in September until early October.

Cranberries, except when water raked, should be gathered only when the vines are dry. A frosty night compels the flooding of unpicked areas, and usually little harvesting can be done the next day.

Methods of Picking

Hand Picking. This method or one involving the use of "snaps" is commonly used in young fields where the roots are easily torn up by rougher handling. Though hand picking is still widely practiced (as in small fields, with the McFarlin variety in Wisconsin, and even in some large fields in New Jersey and Massachusetts) it is largely being superseded by scooping. In the Pacific coast section the greater part of the crop is hand-picked.

The pickers consist of a number of families. Management and housing of this labor for two months constitutes a big problem. If 30,000 bushels of cranberries are to be picked by October 20, or in 40 working days, 750 bushels must be picked daily, and, if the pickers average 3–4 bushels, 200–250 pickers would be needed.[37]

Marking off a bog with stakes and lines for the pickers has been followed in some localities in a small way, but it is not now the general practice. Such a system is considered too fussy and troublesome by most large growers.

The pickers place the berries in wooden boxes holding one fourth as much as a storage crate. Berries picked from along ditch borders are

Picking cranberries with scoops. (Courtesy, H. J. Franklin, Massachusetts Cranberry Station.)

comparatively poor keepers and should usually be kept separate from the main crop.

SCOOPING. A cranberry scoop is an instrument with teeth so arranged that the operator can comb through the vines, taking off the berries, and catch them in a box-like compartment behind the teeth. The Wisconsin rake or scoop differs from the eastern scoop chiefly in having a long handle which permits its use while one is standing.

An ordinary laborer with a little practice is able to average 6–12 bushels a day with a scoop, and experienced scoopers average over 20 bushels under favorable conditions in New Jersey. The average is somewhat higher in Massachusetts; here, a foreman, 15 scoopers, and three helpers are needed to pick a 15-acre bog, including the taking of the berries from the bog and piling on the upland for carting.

Scooping the vines in one direction year after year tends to draw them uniformly, decrease damage, and increase the speed of harvesting. In Massachusetts, after harvest, the vines are raked hard, in the direction opposite to that in which they were scooped, with hand hay rakes. This raking clears the bog of the loose vines torn up by the scoops and trains the vines for scooping the next year.

WATER RAKING. This is practiced only in Wisconsin, where the pre-

vailing low humidity and drying winds make it possible to dry the berries in a short time. In this method, a shallow flood is put on the bog, and the berries are raked off as they float on or near the surface of the water.

Water raking almost completely eliminates harvesting losses and at the same time reduces vine injury to a minimum. Under favorable drying conditions the crop can be harvested more rapidly than by any other method, though it is doubtful whether the total harvest cost is less than dry scooping because of the extra handling and equipment required. The chief disadvantage is the effect on keeping quality, as it leads to more rot than does dry raking. Nevertheless, more than half the Wisconsin crop is water raked, and the growers feel that the advantages outweigh its drawbacks.

Small flooding sections are a distinct advantage in water raking, as the berries then need be kept in water only a short time. The sections should not be larger than can be harvested in a day by the usual picking crew. Only cool water should be used. Well-colored berries keep better than immature ones when water raked. The berries must be thoroughly dry when stored, and those lots that are slow in drying because of unfavorable weather or other conditions should be kept separate in order that they may be watched for possibly impaired keeping quality.

Two systems of drying are in current use: (a) the berries are spread thinly in drying crates just as they come from the bog, the crates are stacked loosely in an exposed position, and the berries are left undisturbed until dry; (b) most of the vines and trash are removed from the berries before drying by means of wire screens or revolving canvas belts. The berries dry more rapidly with the debris removed but are subjected to extra handling at increased labor cost. The crate most commonly used for drying berries is two feet square and four inches deep and has two sides and the bottom made of lath. Cleats on the bottom edges hold the crates apart when they are stacked for drying. The drying crate also serves for storing the berries.

Handling the Crop

Cranberries are best picked during dry weather. When frosty nights compel the flooding of unpicked areas, usually no picking should be done the next day. The berries are stored in a warehouse until shipped.

The American Cranberry Exchange was formed in 1907 to act as

National Sales Agency for the three original state companies in Massachusetts, New Jersey, and Wisconsin. This is one of the oldest farmers' marketing cooperatives in existence. The Coos Cranberry Cooperative of Bandon, Ore., was accepted as an affiliate in 1947.

Storing

Adequate ventilation is essential to color up partly ripe berries in storage; prevent actual smothering by storage in too close containers, especially at high temperatures; and, avoid increased loss from decay due to partial smothering. Recognition of these facts has been a factor leading to the adoption of ventilated half- or quarter-barrel boxes as the standard shipping package and to the use of ventilated boxes for storage of the fruit before it is cleaned for market.

In New Jersey,[41] harvested cranberries showed no color increase between 33° and 34° F., even in light. Between 55° and 60°, excellent color was produced. Berries did not keep well for 21 days at 68° to 77°. Freezing of berries broke down tissues and permitted the red pigments to diffuse into the juice.

In Massachusetts[337] the highest sugar content was attained in fruits which ripened fully on the vines. In storage there was a steady loss of sugar by respiration. Total acid decreased gradually, but the tart flavor was maintained as long as cranberries remained sound. In 43 varieties from Massachusetts the average composition was 12.36 per cent dry matter, 2.3 per cent acid, and 4.13 per cent sugar. In 13 New Jersey varieties the corresponding figures were 12.03, 2.35, and 3.74; and for 12 Wisconsin varieties, 11.63, 2.41, and 3.54. Since acid varies within rather narrow limits and sugar in a wide range, quality seems closely related to sugar content. Nine Massachusetts and one New Jersey variety equaled or exceeded 5 per cent sugar. In cold storage, 10 varieties had 60 per cent of sound berries on April 1, four varieties were half rotted by January 15, and the remaining varieties attained this condition by the end of February, indicating some limits to cold storage.

The storage temperature is best kept between 35° and 40° F., without much fluctuation. Good circulation of air is necessary. In the colder sections, artificial heat is required to prevent freezing. Before building an elaborate storehouse a careful study should be made of the subject, par-

ticularly of the latest developments in construction, materials, and manipulation. In some cases, houses simply with wide cracks in the walls to allow free ventilation have been used, but in such cases the satisfactory storage period has been rather short.

The behavior of cranberries placed in an electric incubator at a uniform 32° C. (89.6° F.) for a week early in the fall is a fair key to their future behavior in ordinary storage; for instance, a comparison of incubator tests with actual keeping tests upon two lots, one dusted and one untreated, showed 0 and 4.9 per cent rot in the incubator and 7 and 33 per cent in storage.

These three weather elements that influence the size of cranberries in Massachusetts[21,36] affect the keeping quality also: (a) amount of sunshine the year before the crop year—the more sun, the larger the cranberries and the poorer their keeping quality; (b) sunshine and mean temperature of March of the crop year—the more sunshine and the lower the mean temperature, the smaller and sounder the cranberries; (c) amount of precipitation in July and August of the crop year—the more rain, the larger the berries and the poorer their keeping quality.

It is a good plan to provide a place in the storehouse where berries which have become wet can be dried before the crates are piled or stacked. When cranberries are taken from a cool to a warm room (differences in humidity), water condenses on their shiny skins. Such berries keep poorly.

Sorting

In preparation for market, the berries first go through a separator. The flesh of the sound berry is more elastic than that of the rotted berry. The fact is made use of in sorting. The berries after screening drop on a series of stairs or bounding boards at an inclined plane; the sound ones bounce to one compartment and the soft ones slide or roll into another. Spotted berries, which are firm on one side, frequently go into the sound berry compartment. These are taken out by hand, usually from off a moving belt on which the berries are delivered from the machine.

A rise in temperature of 18° F. cuts the life of cranberries in half;[33,37] that is, if a bushel of cranberries is picked during the middle of a warm day when the berries have a temperature of 82° and the fruit is stored in a building in which this temperature is maintained, it will keep only half as long as a bushel picked earlier

Hand sorting cranberries at packing house. (Courtesy, H. J. Franklin, Massachusetts Cranberry Station.)

in the day when the temperature of the berries is 64° and the fruit is placed promptly in a cool storehouse which maintains this temperature. Actually, however, berries picked and held at the higher temperature rarely keep half as long as those at the lower temperature, because decay fungi grow faster at the higher temperature.[215]

One very desirable change which the introduction of the method of sorting cranberries on moving belts has made possible is that the belts can be run through a small, well-lighted, and comfortably warm room, where the hand sorters work while the separating machinery at one end of the belt and the packing at the other end are outside the room and in much lower temperature. The berries are thus exposed to a relatively high temperature for only a fraction of a minute and do not become warmed up to any extent in the process.

Market Containers

Up to about 1920, the barrel, holding 85 quarts or 100 pounds of cranberries, was the standard package. At present, the barrel is practically obsolete as a container for cranberries. The half-barrel box is used a little, but the quarter-barrel box is now the standard package.

References

1. Aamodt, T. L., and W. G. Brierley: Winter storage of strawberry plants, *Proc. Am. Soc. Hort. Sci.*, **35**:504–507, 1938.
2. Addoms, R. M., and F. C. Mounce: Nutrient requirements of the cranberry, *Plant Physiol.*, **6**:653–668, 1931.
3. ———, and ———: Further notes on the nutrient requirements of the cranberry, *Plant Physiol.*, **7**:643–656, 1932.
4. Alderman, W. H.: New fruits produced at the University of Minnesota Fruit Breeding Farm, *Minn. Dept. Agr., Dairy, Food, Ann. Feed Bull.* 230, 1926.
5. Amerine, M. A., and A. J. Winkler: Titratable acidity, pH, and organic acid content, *Proc. Am. Soc. Hort. Sci.*, **40**:313–324, 1942.
6. Anderson, L. C.: Four years of commercial fertilizers on currants, *N.Y. Bull.* 641, 1934.
7. Anderson, R. J.: The anthocyans in Norton and Concord grapes, *J. Biol. Chem.*, **57**:795, 1923.
8. ———, and F. P. Nabenhauer: Anthocyans appearing in the pigment of Isabella grapes, *N.Y. Tech. Bull.* 123, 1926.
9. ———, and ———: Chemical studies in grape pigments, *N.Y. Bull.* 146, 1928.
10. Angelo, E.: The recovery of grape vines when the young shoots are killed by spring frosts, *Proc. Am. Soc. Hort. Sci.*, **19**:29–32, 1923.
11. ———: Fruiting behavior of Concord canes of various diameters, *Proc. Am. Soc. Hort. Sci.*, **24**:155–156, 1928.
12. ———, *et al.*: Factors relating to hardiness in the strawberry, *Minn. Bull.* 135, 1939.
13. Anthony, R. D.: Notes on the breeding of raspberries, *N.Y. Bull.* 417, 1916.
14. Asbury, C. E., *et al.*: Studies on the "raisining" of Alexandria (Muscat) grapes in transit, *U.S. Dept. Agr. Dep. Circ.* 574, 1940.
15. Bailey, J. S.: Pollination of the cultivated blueberry, *Proc. Am. Soc. Hort. Sci.*, **35**:71–72, 1938.
16. ———, and H. N. Everson: Chlorosis of cultivated blueberry, *Proc. Am. Soc. Hort. Sci.*, **35**:495–496, 1938.
17. ———, and A. P. French: Identification of blueberry varieties by plant characters, *Mass. Bull.* 431, 1946.
18. ———, *et al.*: Blueberry culture, *Mass. Bull.* 358, 1941.
19. ———, and H. J. Franklin: Blueberry culture, *Mass. Bull.* 317, 1935.

20. Bailey, L. H.: North American blackberries, in "Gentes Herbarum," vol. 2, art. 12. Ithaca, N. Y. 1932.
21. ———: Vires peculiares as American borealem, in "Gentes Herbarum," 3. Fasc. iv: 151–244, 1934.
22. Bain, H. F.: Cranberry industry, *Wisc. Dep. Agr. Bull.* 96, 1929.
23. ———, *et al.:* Harvesting and handling cultivated blueberries, *U.S. Dep. Agr. Bull.* 1882, 1942.
24. Baker, C. E.: Fertilizing strawberries, *Purdue Leaf.* 169, 1933.
25. Baker, R. E., and S. Wilhelm: Boysenberries, youngberries, nectarberries, loganberries, *Am. Fr. Grow.*, April, 1947.
26. Ball, E.: A note on strawberry "strains," *J. Bath, West and Southern Counties Soc. Encour. Agr.*, 200–204, 1926.
27. ———, and C. E. T. Mann: Influence of some cultural practises on the normal development of the strawberry plant, *J. Pomology Hort. Sci.*, 6:104–112, 1927.
28. Barber, C. W.: Cranberry acreage and production, *Mass. Dep. Agr.*, vol. 16, 1925.
29. Barnard, C.: Fruit bud studies, *J. Council Sci. Ind. Research*, Canberra, Australia, 16, 1932.
30. Bates, J. C.: Comparative anatomical research within the genus Ribes, *Univ. Kans. Sci. Bull.*, **21**:369–398, 1933.
31. Beach, F. H.: Grape growing, *Ohio Bull.* 250, 1944.
32. Beach, G. A.: Fruiting habit of the black raspberry, *Colo. Tech. Bull.* 8, 1934.
33. ———: Latham, Cuthbert, and June raspberries under hillrow and hedgerow training, *Proc. Am. Soc. Hort. Sci.*, **35**:497–500, 1938.
34. ———, and L. R. Bryant: Grape growing, *Colo. Bull.* 484, 1944.
35. Beckwith, C. S.: Effect of fertilizer on blueberries, *Soil Sci.*, **10**:309–312, 1920.
36. ———: Cranberry growing, *N.J. Cir.* 144, 1922.
37. ———: Cranberry growing, *N.J. Cir.* 246, 1931.
38. ———: Cranberry and blueberry investigations, *N.J. Ann. Rpt.* 170–174, 1930.
39. ———: Sanding cranberry bogs, *N.J. Cir.* 371, 1937.
40. ———: Locating and preparing fields for the cultivated blueberry, *N.J. Cir.* 473, 1943.
41. ———, and B. R. Fudge: Cranberry and blueberry investigations, *N.J. Rpt.*, 1929.
42. ———, and H. H. Weiss: A survey of the cranberry industry, *N.J. Dep. Agr. Cir.* 45, 1922.
43. ———, and S. Colville: Blueberry culture, *N.J. Cir.* 200, 1927.
44. Bedford, C. L., *et al.:* Locker and home freezing of farm products, *Wash. Bull.* 180, 1945.
45. Berger, A. A.: A taxonomic review of currants and gooseberries, *N.Y. Tech. Bull.* 109, 1924.

46. Bioletti, F. T.: Selection of planting stock for vineyards, *Hilgardia*, **2**:1–33, 1926.
47. ———: Elements of grape growing, *Calif. Cir.* 30, 1929.
48. Blair, J. C.: Some Midwest contributions to American pomology, *Am. Pom. Soc.*, 169–186, 1921.
49. Blosser, J. H., *et al.*: Man labor requirements for cane fruits, *Ore. Bull.* 422, 1944.
50. Boller, C. A., and R. E. Stephenson: Some effects of mulches on soil properties, *Proc. Am. Soc. Hort. Sci.*, **48**:37–39, 1946.
51. Brainerd, E., and A. K. Pettersen: Blackberries of New England, *Vt. Bull.* 217, 1920.
52. Bregger, J. T.: Use of the survey method in showing cultural factors in red raspberry production, *Proc. Am. Soc. Hort. Sci.*, **28**:200–205, 1932.
53. Brierley, W. G.: Blueberry culture in Minnesota, *Proc. Am. Soc. Hort. Sci.*, **17**:243–249, 1921.
54. ———: Cambial activity in the red raspberry cane in the second season, *Proc. Am. Soc. Hort. Sci.*, **26**:278–280, 1930.
55. ———: Senescence in the red raspberry cane, *Minn. Tech. Bull.* 69, 1930.
56. ———: Transpiration rates in old and new canes of Latham raspberry as measured by non-toxic dyes, *Proc. Am. Soc. Hort. Sci.*, **27**:152–157, 1931.
57. ———: Effect of height of pruning on size of berries and yield in the Latham raspberry, *Minn. Bull.* 281, 1931.
58. ———: Notes on the fall flowering habit of the red raspberry, *Proc. Am. Soc. Hort. Sci.*, **28**:180–181, 1932.
59. ———: Growth studies in the Latham raspberry, *Proc. Am. Soc. Hort. Sci.*, **28**:182–187, 1932.
60. ———: Transpiration in new and old canes of the Latham raspberry, *Proc. Am. Soc. Hort. Sci.*, **28**:188–193, 1932.
61. ———: Effect of removal of fruiting canes after harvest upon the growth of new canes in the Latham raspberry, *Proc. Am. Soc. Hort. Sci.*, **29**:300–301, 1933.
62. ———: Response of the Latham raspberry to pruning, *Minn. Tech. Bull.* 100, 1934.
63. ———: Absorption of water by red raspberry foliage, and some evidence relative to the movement of water within the plant, *Proc. Am. Soc. Hort. Sci.*, **34**:385–388, 1937.
64. ———: Questions on hardiness in raspberries, *Minn. Fr. Grow.* July, 1945.
65. ———: Why do hardy raspberries winterkill?, *Minn. Hort.* Oct., 1945.
66. ———, and A. C. Hildreth: Studies on the hardiness of Vaccinium, *Plant Physiol.*, **3**:303–308, 1928.
67. ———, and R. H. Landon: Evidence relating to the downward movement of photosynthate in fruiting canes of the red raspberry, *Proc. Am. Soc. Hort. Sci.*, **34**:377–380, 1937.

68. ———, and ———: Effect of time of mulching on cold resistance of strawberry plants, *Proc. Am. Soc. Hort. Sci.*, **38**:424–426, 1941.
69. ———, and ———: Experimental "smothering" of dormant strawberry plants, *Proc. Am. Soc. Hort. Sci.*, **40**:361–366, 1942.
70. ———, and ———: Cold resistance of strawberry plants in the early stages of growth, *Proc. Am. Soc. Hort. Sci.*, **42**:432–434, 1943.
71. ———, and ———: Winter behavior of strawberry plants, *Minn. Bull.* 375, 1944.
72. ———, and ———: Cold resistance of the roots of the Latham red raspberry, *Proc. Am. Soc. Hort. Sci.*, **47**:215–218, 1947.
73. ———, and ———: Some relationships between rest period, rate of hardening, loss of cold resistance and winter injury in the Latham raspberry, *Proc. Am. Soc. Hort. Sci.*, **47**:224–234, 1947.
74. ———, and J. D. Winter: Growing red raspberries for market, *Minn. Ext. Bull.* 199, 1939.
75. ———, *et al.:* Effect of ice upon the survival of strawberry plants, *Proc. Am. Soc. Hort. Sci.*, **37**:557–563, 1940.
76. Brightwell, W. T.: Yield, size of berries, and season of maturity of the highbush blueberry as influenced by severity of pruning, *Proc. Am. Soc. Hort. Sci.*, **38**:447–450, 1941.
77. Brooks, A. N.: Strawberry production, *Fla. Bull.* 125, 1945.
78. ———, *et al.:* Strawberry production, *Fla. Bull.* 63, 1932.
79. Brown, W. S.: The cranberry, *Ore. Bull.* 225, 1927.
80. Bryant, L. R.: Raspberry production, *Colo. Bull.* 385A, 1945.
81. ———, and G. Beach: Strawberry production, *Colo. Bull.* 418, 1943.
82. Bush, C. D.: Raspberry crops and quality depend on fertilizers, *Better Fruit*, Feb., 1930.
83. Caldwell, J. S.: Effects of seasonal conditions upon the chemical composition of American grape juices, *J. Agr. Research*, **30**:1133–1176, 1925.
84. Calma, V. C., and H. W. Richey: Growth of Concord grape cuttings in relation to vigor, chemical composition and relative position on the cane, *Proc. Am. Soc. Hort. Sci.*, **28**:131–136, 1932.
85. Carlton, H.: Home-preparation of fruits and vegetables for the freezer-locker, *Tenn. Publ.* 280, 1944.
86. Carrick, D. B.: Cold-storage and freezing studies of the fruit of the vinifera grape, *Cornell Univ. Agr. Exp. Sta. Mem.* 131, 1930.
87. Chandler, F. B.: Effect of lime on the lowbush blueberry, *Proc. Am. Soc. Hort. Sci.*, **36**:477, 1939.
88. ———, and I. C. Mason: Pruning the lowbush blueberry, *Proc. Am. Soc. Hort. Sci.*, **37**:609–610, 1940.
89. ———, and F. Hyland: Botanical and economic distribution of Vaccinium in Maine, *Proc. Am. Soc. Hort. Sci.*, **38**:430–433, 1941.
90. Chandler, W. H.: Responses of bush fruits to fertilizers, *Proc. Am. Soc. Hort. Sci.*, **17**:201–204, 1921.

91. ———: "Fruit Growing," Boston, Houghton Mifflin Co., 1925.
92. ———, and A. J. Heinicke: Effects of pruning on the growth of grape vines, *Proc. Am. Soc. Hort. Sci.*, **22**:74–80, 1926.
93. ——— , *et al.*: Little-leaf or rosette in fruit trees, *Proc. Am. Soc. Hort. Sci.*, **29**:255–263, 1932. (**30**:70–86, 1933. **32**:11–19, 1934.)
94. Cherry, W. F.: Effect of chemical fertilizers upon growth and fruit production of the black raspberry, *Proc. Am. Soc. Hort. Sci.*, **28**:176–179, 1932.
95. Childs, W. H.: Fruiting response of Eldorado blackberries pruned to varying lateral lengths with and without nitrogen fertilizer applications, *Proc. Am. Soc. Hort. Sci.*, **35**:489–491, 1938.
96. ———: Production, berry size, and growth of red raspberries as influenced by mulching, *Proc. Am. Soc. Hort. Sci.*, **42**:463–466, 1943.
97. ———: Shredded sphagnum vs. peat and sand as a medium for transplanted blueberry seedlings, *Proc. Am. Soc. Hort. Sci.*, **47**:206–208, 1946.
98. ———, and M. B. Hoffman: Nitrogen fertilization of Latham red raspberries, *Proc. Am. Soc. Hort. Sci.*, **29**:302–305, 1933.
99. Clark, J. H.: Horticultural investigations, *N.J. Rpt.*, 1925.
100. ———: Effects of pruning on grape production, *Proc. Am. Soc. Hort. Sci.*, **22**:80–84, 1926.
101. ———: Pressure tests of strawberries, *N.J. Agr.*, **12**:9, 1930.
102. ———: Pomology, *N.J. Rpt.*, 1930.
103. ———: Length of the fruit development period of strawberry varieties, *Proc. Am. Soc. Hort. Sci.*, **28**:211–215, 1932.
104. ———: Injury to buds of grape varieties caused by low temperatures, *Proc. Am. Soc. Hort. Sci.*, **34**:408–413, 1936.
105. ———: Effects of mulching red raspberies on growth and production, *Proc. Am. Soc. Hort. Sci.*, **37**:604–608, 1940.
106. ———: Leaf characters as a basis for the classification of blueberry varieties, *Proc. Am. Soc. Hort. Sci.*, **38**:441–446, 1941.
107. ———: Selection of criterion leaves for the identification of blueberry varieties, *Proc. Am. Soc. Hort. Sci.*, **40**:347–351, 1942.
108. Cochran, G. W., and J. E. Webster: Effect of fertilizers on the handling qualities and chemical analyses of strawberries, *Proc. Am. Soc. Hort. Sci.*, **28**:236–243, 1932.
109. Colby, A. S.: Pruning notes on blackberry varieties, *Proc. Am. Soc. Hort. Sci.*, **16**:241–242, 1920.
110. ———: Additional notes on pruning and training grapes, *Proc. Am. Soc. Hort. Sci.*, **22**:415–420, 1926.
111. ———: Horticultural investigations, *Ill. Rpt.*, 1926.
112. ——— : Self-fertility of some gooseberry varieties, *Proc. Am. Soc. Hort. Sci.*, **23**:138–140, 1927.
113. ——— : Recent experimental work in small fruit culture, *Trans. Illinois State Hort. Soc.*, **61**:155–168, 1927.

114. ———: Inheritance of anthracnose resistance in certain raspberry hybrids, *J. Hered.*, **19**:377–382, 1928.
115. ———: New facts regarding the pruning of the Concord grape, *Trans. Illinois State Hort. Soc.*, 1929.
116. ———: Strawberry Club Manual, *Ill. Cir.* 339, 1929.
117. ———: The red raspberry situation, *Trans. Illinois State Hort. Soc.*, 1930.
118. ———: The training of certain grape varieties to the 6-cane Kniffin system, *Proc. Am. Soc. Hort. Sci.*, **26**:274–277, 1930.
119. ———: Bramble fruits, *Ill. Cir.* 427, 1935.
120. ———: Strawberry culture, *Ill. Cir.* 453, 1936.
121. ———: Raspberry root systems, *Proc. Am. Soc. Hort. Sci.*, **34**:372–376, 1937.
122. ———: The Brainerd blackberry in central Illinois, *Proc. Am. Soc. Hort. Sci.*, **37**:593–596, 1940.
123. ———: An evaluation of small fruits, *Trans. Illinois State Hort. Soc.*, **76**:203–225, 1942.
124. ———: Winter injury as a limiting factor in red raspberry growing, *Am. Pom. Soc.*, **59**:13–15, 1943.
125. ———, and A. G. Vogele: Pruning and training Concord grapes, *Proc. Am. Soc. Hort. Sci.*, **20**:384–387, 1924.
126. ———, and L. R. Tucker: Growth and fruit production studies in the grape, *Proc. Am. Soc. Hort. Sci.*, **25**:210–216, 1929.
127. ———, and ———: Effects of pruning on fruiting of shoots and the growth of their terminals and laterals in the Concord, *Proc. Am. Soc. Hort. Sci.*, **28**:143, 1932.
128. Collison, R. C.: Fertilizer experiments with strawberries, *Proc. Am. Soc. Hort. Sci.*, **44**:295–298, 1944.
129. ———, and G. L. Slate: Fertilizer responses of black raspberries, *Proc. Am. Soc. Hort. Sci.*, **42**:463–466, 1943.
130. Cooley, L. M.: The identity of raspberry mosaics, *Phytopathology*, **26**:44–56, 1936.
131. ———: Wild brambles in relation to spread of virus diseases in cultivated black raspberries, *N.Y. Bull.* 665, 1936.
132. ———: Wild bramble eradication, *N.Y. Bull.* 674, 1936.
133. ———: Retarded foliation in black raspberries and its relation to mosaic, *N.Y. Bull.* 675, 1936.
134. Cooper, J. R., and J. E. Vaile: Response of American grapes to various treatments and vineyard practices, *Ark. Bull.* 378, 1939.
135. ———, and ———: Effect of fertilizers, soil reaction and texture, and plant stand on the performance of strawberries, *Ark. Bull.* 454, 1945.
136. Coville, F. V.: Experiments in blueberry culture, *U.S. Dep. Agr. Bull.* 193, 1910.
137. ———: Directions for blueberry culture, *U.S. Dep. Agr. Bull.* 974, 1921.

138. Crane, M. B., and C. D. Darlington: The origin of new forms in Rubus, *Genetics*, **27**:270–273, 1927.
139. Crane, J. D., and I. C. Haut: Influence of various renewal systems and width of row on yields of Blakemore strawberry, *Proc. Am. Soc. Hort. Sci.*, **40**:368–372, 1942.
140. Crowley, D. J.: Cranberry growing, *Wash. Bull.* 230, 1929.
141. ———: The cultivated cranberry, *Wash. Bull.* 349, 1937.
142. ———: Weed control in the cranberry bogs of western Washington, *Proc. Am. Soc. Hort. Sci.*, **37**:623–624, 1940.
143. Crumb, S. E.: Insecticide program for raspberry fruitworm control, *U.S. Dep. Agr. Bur. Entomol. Plant Quarantine Circ.* E433, 1938.
144. Cullinan, F. P.: Effect of heavy and light pruning of grapes during first two growing seasons, *Hoosier Hort.*, Aug., 1932.
145. Culpepper, C. W., *et al.*: A physiological study of development and ripening in the strawberry, *J. Agr. Research*, **50**:645–696, 1935.
146. Cummings, M. B., and E. W. Jenkins: Sterility of strawberries, *Vt. Bull.* 232, 1932.
147. Damner, O.: On the influence of the removal of the runners of strawberry plants upon their fertility, *Gardeners' Chronicle*, **25**:217–218, 1899.
148. Darrow, G. M.: Culture of the Logan blackberry and related varieties, *U.S. Dep. Agr. Bull.* 998, 1918.
149. ———: Strawberry culture, *U.S. Dep. Agr. Bull.* 1028, 1919.
150. ———: Are our raspberries derived from American or European species?, *J. Hered.*, **11**:179–184, 1920.
151. ———: Small fruit, *Proc. N.Y. State Hort. Soc.*, **66**:90–100, 1921.
152. ———: Currants and gooseberries, *U.S. Dep. Agr. Bull.* 1024, 1922.
153. ———: The Van Fleet raspberry, *U.S. Dep. Agr. Bull.* 1403, 1924.
154. ———: Dewberry growing, *U.S. Dep. Agr. Bull.* 1403, 1924.
155. ———: Essentials in strawberry culture, *Am. Fr. Grow.*, **46**:18–19, 1926.
156. ———: Sterility and fertility in the strawberry, *J. Agr. Research*, **34**:393–411, 1927.
157. ———: Development of runners and runner plants in the strawberry, *U.S. Dep. Agr. Tech. Bull.* 122, 1929.
158. ———: Inflorescence types of strawberry varieties, *Am. J. Botany*, **16**:571–585, 1929.
159. ———: Experimental studies on the growth and development of strawberry plants, *J. Agr. Research*, **41**:307–325, 1930.
160. ———: Effect of light, temperature and transpiration on elongation of canes of raspberry and other brambles, *Proc. Am. Soc. Hort. Sci.*, **26**:308–311, 1930.
161. ———: European blackberry seedlings and hybrids, *J. Hered.*, **22**:143–146, 1931.
162. ———: Effect of fertilizers on firmness and flavor of strawberries in North Carolina, *Proc. Am. Soc. Hort. Sci.*, **27**:231–235, 1931.

163. ———: Blackberry growing, *U.S. Dep. Agr. Bull.* 1399, 1932.
164. ———: Strawberry culture, *U.S. Dep. Agr. Bull.* 1026, 1933.
165. ———: Maytime, Starbright, and Redstar strawberries, *U.S. Dep. Agr. Dep. Circ.* 597, 1940.
166. ———: Rest period requirements for blueberries, *Proc. Am. Soc. Hort. Sci.*, **41**:189–194, 1942.
167. ———, and C. Dearing: Culture and handling of the Blakemore strawberry, *N.C. Bull.*, Nov., 1934.
168. ———, and S. B. Detwiler: Currants and gooseberries, *U.S. Dep. Agr. Bull.* 1398, 1930.
169. ———, *et al.*: Establishing cranberry fields, *U.S. Dep. Agr. Bull.* 1400, 1924.
170. ———, *et al.*: Managing cranberry fields, *U.S. Dep. Agr. Bull.* 1401, 1924.
171. ———, and A. E. Longley: Cytology and breeding of Rubus macropetalus, the Logan, and related blackberries, *J. Agr. Research*, **47**:315–330, 1933.
172. ———, and J. R. Magness: Mulching red raspberries, *Proc. Am. Soc. Hort. Sci.*, **36**:481–484, 1939.
173. ———, and H. Sherwood: Seed and berry size of cane fruits, *Proc. Am. Soc. Hort. Sci.*, **28**:194–199, 1932.
174. ———, and ———: Transpiration studies on strawberries, *Proc. Am. Soc. Hort. Sci.*, **28**:225–230, 1932.
175. ———, and G. F. Waldo: Fruit-bud formation in the strawberry in spring in Southeastern States, *Science*, **72**:349–350, 1930.
176. ———, and ———: Bellmar, Southland, and Redheart strawberries, *U.S. Dep. Agr. Dep. Circ.* 171, 1931.
177. ———, and ———: Strawberry varieties, *U.S. Dep. Agr. Bull.* 1043, 1931.
178. ———, and ———: Brainerd blackberry, *U.S. Dep. Agr. Dep. Circ.* 220, 1932.
179. ———, and ———: Glenndale gooseberry, *U.S. Dep. Agr. Dep. Circ.* 223, 1932.
180. ———, and ———: Effect of fertilizers on plant growth, yield, and decay of strawberries, *Proc. Am. Soc. Hort. Sci.*, **29**:318–324, 1933.
181. ———, and ———: Responses of strawberry varieties and species to duration of the daily light period, *U.S. Dep. Agr. Tech. Bull.* 453, 1934.
182. ———, and ———: Raspberry culture, *U.S. Dep. Agr. Bull.* 887, 1941.
183. ———, *et al.*: Blueberry growing, *U.S. Dep. Agr. Bull.* 1951, 1944.
184. Davis, L. L.: Youngberry, boysenberry, nectarberry, and dewberry growing, *Tenn. Spec. Circ.* 245, 1945.
185. Davis, M. B.: Strawberry culture, *Dom. Can. Exp. Farms Hort. Rpt.*, 1931.
186. ———: Correlations in the strawberry, *Proc. Am. Soc. Hort. Sci.*, **18**:260–263, 1922.
187. ———: The cranberry, *Can. Dep. Agr. Bull.* 19, 1923.
188. ———, and H. Hill: Nutritional studies with Fragaria, *Sci. Agr.*, **8**:683–697, 1928.
189. ———, *et al.*: The cranberry industry, *Can. Dep. Agr. Bull.* 180, 1935.

190. Dearing, C.: Muscadine grapes, *U.S. Dep. Agr. Bull.* 1785, 1938.
191. Demaree, J. B.: Diseases of strawberries, *U.S. Dep. Agr. Bull.* 1891, 1941.
192. ———: Control of grape diseases and insects, *U.S. Dep. Agr. Bull.* 1893, 1942.
193. Diehl, H. C., *et al.*: The frozen-pack method of preserving berries in the Pacific Northwest, *U.S. Dep. Agr. Tech. Bull.* 148, 1930.
194. ———, and J. A. Berry: The temperature factor in the freezing preservation of fruits and vegetables, *Proc. Am. Soc. Hort. Sci.*, **29**:287–290, 1933.
195. Dix, I. W., and J. R. Magness: American grape varieties, *U.S. Dep. Agr. Bull.* 437, 1937.
196. Dochlbert, C. A.: Blueberry tillage problems and a new harrow, *N.J. Bull.* 625, 1937.
197. ———: Dates for applying fertilizer, *Proc. Am. Soc. Hort. Sci.*, **38**:451–454, 1941.
198. ———: Propagating blueberries from hardwood cuttings, *N.J. Circ.* 490, 1945.
199. Doran, W. L., and J. S. Bailey: Propagation of the highbush blueberry by softwood cuttings, *Mass. Bull.* 410, 1943.
200. Dorsey, M. J.: Pollen development in the grape with special reference to sterility, *Minn. Bull.* 144, 1914.
201. Duis, W. H.: Selection of the lowbush blueberry in West Virginia, *Proc. Am. Soc. Hort. Sci.*, **38**:434–437, 1941.
202. Eaton, E. L.: The blueberry, *Can. Dep. Agr. Bull.* 754, 1943.
203. Egbert, R. L.: Retarding the ripening of strawberries, *Mich. State Coll. Agr. Quart. Bull.*, **23**:20–26, 1940.
204. Eidt, C. C., and M. MacArthur: Dehydration of blueberries, *Food in Canada*, Dec., 1944.
205. Einset, O.: Open pollination vs. hand pollination of pollen-sterile grapes, *N.Y. Tech. Bull.* 162, 1930.
206. Elsea, S. A.: My experience in growing strawberries, *Proc. Ohio State Hort. Soc.*, **65**:212–214, 1932.
207. Faurot, F. W.: Newer practices in grape growing, *Mo. Hort. Soc.* pp. 144–149, 1930.
208. ———, and T. J. Talbert: A comparison of four systems of pruning grapes, *Mo. Res. Bull.* 121, 1928.
209. Filinger, G. A.: Preserving food in home frozen food cabinets, *Kans. Circ.* 230, 1945.
210. Fletcher, S. W.: North American varieties of the strawberry, *Va. Tech. Bull.* 11, 1916.
211. Franklin, H. J.: Report of the cranberry substation for 1916, *Mass. Bull.* 180, 1917.
212. ———: Eighth report of the cranberry station, *Mass. Bull.* 206, 1921.
213. ———: Cranberry growing, *Mass. Leaf.* 72, 1923.
214. ———: Cranberry growing, *Mass. Bull.* 371, 1940.

215. ———, *et al.:* Cranberry harvesting and handling, *U.S. Dep. Agr. Bull.* 1402, 1924.
215a. ———, and N. E. Stevens: Weather and water as factors in cranberry production, *Mass. Bull.* 433, 1946.
216. Gardner, V. R.: Nutrition of the strawberry, *Mo. Res. Bull.* 57, 1923.
217. ———, F. C. Bradford, and H. D. Hooker: "Fundamentals of Fruit Production," New York, McGraw-Hill Book Co., 1922.
218. Gladwin, F. E.: Winter injury of grapes, *N.Y. Bull.* 433, 1917.
219. ———: A test of commercial fertilizers for grapes, *N.Y. Bull.* 458, 1919.
220. ———: A test of methods in pruning the Concord grape in the Chautauqua grape belt, *N.Y. Bull.* 464, 1919.
221. ———: The behavior of American grapes grafted on vigorous stocks, *N.Y. Bull.* 508, 1924.
222. ———: A correlation between color of grape leaves at time of foliation and fruit color, *N.Y. Tech. Bull.* 107, 1924.
223. ———: The grafting of American grapes, *N.Y. Bull.* 520, 1924.
224. ———: Pruning and training American grapes, *Proc. Ohio State Hort. Soc.*, pp. 43–48, 1926.
225. ———: Grafting grapes, *N.Y. Dep. Agr., Markets Circ.* 97, 1928.
226. ———: Grape pruning, *N.Y. Dep. Agr., Markets Circ.* 104, 1928.
227. ———: A history of American grape growing, *Rural New Yorker*, April 25, 1931.
228. ———: A history of grape-growing in the Eastern United States, *Rural New Yorker*, Aug. 8, 1931.
229. ———: Grafting American grapes on vigorous stocks, *N.Y. Bull.* 607, 1932.
230. ———: Grape culture, *N.Y. Dep. Agr., Markets Circ.* 110, 1932.
231. Goethe, H.: "Handbücher Ampelographie," Berlin, 1887.
232. Goff, E. S.: Investigations of flower buds, *Wisc. Ann. Rpt.*, **17**:266–285, 1900.
233. Gray, G. F.: Strawberry culture, *Okla. Bull.* B-304, 1947.
234. Green, E. L., and Z. I. Kertesz: Studies of the chemistry of grape juice, *N.Y. Tech. Bull.* 181, 1931.
235. Grigsby, B. H.: Physiological investigations of red raspberry plants inoculated with red raspberry mosaic, *Mich. State Coll. Agr. Tech. Bull.* 160, 1938.
236. Haller, M. H.: Respiration of strawberry and raspberry fruits, *U.S. Dep. Agr. Dep. Circ.* 613, 1941.
237. ———, *et al.:* The interrelation of firmness, dry weight, and respiration in strawberries, *Proc. Am. Soc. Hort. Sci.*, **29**:330–334, 1933.
238. Hanson, A. J., and R. L. Webster: Insects of the blackberry, raspberry, strawberry, currant, and gooseberry, *Wash. Bull.* 155, 1938.
239. Hanson, H. C.: Comparison of root and top development in varieties of strawberries, *Am. J. Botany*, **18**:658–673, 1931.
240. Hardy, M. B.: Self and cross fertility of red raspberry varieties, *Proc. Am. Soc. Hort. Sci.*, **28**:118–121, 1932.
241. Havis, L.: Mulching black raspberries, *Ohio Bimo. Bull.*, **22**:18–20, 1937.

242. ———: Freezing injury to strawberry flower buds, flowers, and young fruits, *Ohio Bimo. Bull.*, **22**:168–172, 1938.
243. ———: Frost injury to raspberry flower buds, *Ohio Bimo. Bull.*, **23**:139–141, 1938.
244. ———: Distribution of black raspberry roots under mulch and cultivation, *Ohio Bimo. Bull.*, **24**:81–88, 1939.
245. ———: Strawberry production, *Ohio Bull.* 626, 1942.
246. Hedrick, U. P., *et al.*: "Grapes of New York," Albany, N. Y., J. B. Lyon Co., 1908.
247. ———: "Small Fruits of New York," Albany, N. Y., J. B. Lyon Co., 1925.
248. Hendrickson, A. H.: Bush fruit culture, *Calif. Circ.* 25, 1929.
249. Hewitt, W. B., and H. F. Jacob: Effect of zinc on yield and cluster weight in Muscat grapes, *Proc. Am. Soc. Hort. Sci.*, **46**:256–262, 1945.
250. Hildreth, A. C.: Propagation of the lowbush blueberry, *Proc. Am. Soc. Hort. Sci.*, **26**:91–92, 1932.
251. Hill, H., and M. B. Davis: Studies in fruit-bud differentiation, *Can. Dep. Agr. Bull.* 110, 1929.
252. Hoddy, H. J.: "Strawberry growing along the lines of the Louisville & Nashville Railroad," Farmers Handbook 2, L & N Railroad Co., 1930.
253. Hoffman, M. B.: Grape production, *N.Y. Bull.* 375, 1937.
254. ———, and G. R. Schlubatis: The significance of soil variation in raspberry culture, *Mich. Spec. Bull.* 177, 1928
255. Holland, C. S.: Fertilizers for raspberries, *Ohio Farmer*, April 30, 1927.
256. ———: Raspberry experiments, *Ohio Farmer*, Sept. 3, 1927.
257. ———: Grape fertilizer demonstrations in Ohio, *Proc. Am. Soc. Hort. Sci.*, **27**:161–163, 1931.
258. ———: Results from grape fertilizers, *Proc. Ohio State Hort. Soc.*, **65**:215–219, 1932.
259. Hooper, C. H.: Pollination and setting of fruit blossoms and their insect visitors, *J. Roy. Hort. Soc.*, **38**:238–248, 1913.
260. Hopkins, E. F., and J. H. Gourley: Nitrogen fertilization and the pectic materials in grapes, *Proc. Am. Soc. Hort. Sci.*, **27**:164–169, 1931.
261. Hunt, E. M.: Growing strawberries, *Minn. Ext. Bull.* 72, 1941.
262. Husmann, G. C.: Grape propagation, pruning and training, *U.S. Dep. Agr. Bull.* 471, 1924.
263. ———: Grape districts and varieties in the United States, *U.S. Dep. Agr. Bull.* 1689, 1932.
264. ———, *et al.*: Testing vinifera grape varieties grafted on phylloxera-resistant rootstocks in California, *U.S. Dep. Agr. Tech. Bull.* 697, 1939.
265. Ichijima, K.: Cytological and genetical studies in Fragaria, *Genetics*, **11**:590–604, 1926.
266. Jacob, H. E.: Girdling Thompson Seedless vines for the production of fine table grapes, *Blue Anchor*, **7**:8–29, 1930.
267. Jacob, H. E.: Propagation of grapevines, *Calif. Circ.* 101, 1936.

267a. ———: Grape growing, *Calif. Circ.* 116, 1947.
268. Johnson, N. W., and G. Severance: An economic study of berry farming in Western Washington, *Wash. Bull.* 204, 1926.
269. Johnston, S.: Winter pruning the black raspberry, *Mich. State Coll. Agr. Spec. Bull.* 143, 1925.
270. ———: Cuthbert raspberry stock, *Mich. State Coll. Agr. Quart. Bull.*, **8**:182–183, 1925.
271. ———: Insects aid fruit setting of raspberry, *Mich. State Coll. Agr. Quart. Bull.*, **9**:105–106, 1929.
272. ———: Selected raspberry plants cut disease losses, *Mich. State Coll. Agr. Quart. Bull.*, **11**:198, 1929.
273. ———: Some observations on raspberry culture, *Am. Fruit Grower*, Jan., 1931.
274. ———: The propagation of the highbush blueberry, *Mich. State Coll. Agr. Spec. Bull.* 202, 1930.
275. ———: The value of plant and tip selection in the propagation of the black raspberry, *Mich. State Coll. Agr. Quart. Bull.*, **13**:195–199, 1931.
276. ———: Cultivation of the highbush blueberry, *Mich. State Coll. Agr. Spec. Bull.* 252, 1934.
277. ———: Propagating lowbush and highbush blueberry plants by means of small side roots, *Proc. Am. Soc. Hort. Sci.*, **33**:372–375, 1936.
278. ———: Essentials of blueberry culture, *Mich. State Coll. Agr. Spec. Bull.* 188, 1943.
279. ———, and R. E. Loree: Pruning the red raspberry, *Mich. State Coll. Agr. Spec. Bull.* 162, 1927.
280. Judkins, W. P.: Effect of straw mulch, cultivation, and nitrogen fertilizer on the growth and yield of Latham raspberries, *Ohio Bimo. Bull.*, **29**:154–158, 1944.
281. Keffer, C. A.: Fruiting habit of the grape, *Tenn. Bull.* 77, 1906.
282. Kelly, C. B.: The grape in Ontario, *Ont. Bull.* 438, 1944.
283. Kelly, V. W.: Grape pruning, *Ill. Bull.* 468, 1937.
284. Kelsall, A.: Mulches on small fruits, *Ann. Rept. Nova Scotia Fruit Growers' Assoc.*, **83**:69–71, 1946.
285. Khanmai, M. A., and W. S. Brown: Correlations between leaf area and leaf weight and between leaf weight and fruit production of red raspberries, *Proc. Am. Soc. Hort. Sci.*, **37**:589–592, 1940.
286. Kimbrough, W. D.: Horticulture, *Ala. Rpt.*, 1920.
287. ———: Effect of fertilizer on the quality and on the keeping and carrying qualities of strawberries, *Proc. Am. Soc. Hort. Sci.*, **28**:224, 1932.
288. Knight, L., and T. Wallace: Effects of various manurial treatments on the chemical composition of strawberries, *J. Pomology Hort. Sci.*, **10**:147–180, 1932.
289. Knowlton, H. E.: Growing raspberries, *W. Va. Circ.* 72, 1937.
290. Kramer, A., *et al.*: Effect of mulches and fertilizers on yield and survival of

the dryland and highbush blueberries, *Proc. Am. Soc. Hort. Sci.*, **38**:455–461, 1941.
291. Lacroix, D. S.: Cranberry flower-bud investigations, *J. Agr. Research*, **33**:355–363, 1926.
292. Latimer, L. P.: Response of strawberries to boron, *Proc. Am. Soc. Hort. Sci.*, **42**:441–443, 1943.
293. Lineberry, R. A., *et al.*: Results of strawberry fertilizer and tillage experiments, *N.C. Agron, Inform. Cir.* 64, 1931.
294. Locklin, H. D.: Relation of season of pruning out old cuthbert raspberry canes to amount of winter injury, *West Wash. Bull.* 9 W, 1928.
295. ———: Berry cultivation, *West Wash. Bull.* 16, 1930.
296. ———: Winter pruning and training of cane berries, *Better Fruit*, Feb., 1930.
297. ———: Soil drainage in the berry field, *Better Fruit*, Dec., 1930.
298. ———: Fall work in cane berry fields, *Better Fruit*, Oct., 1930.
299. ———: Blueberries in cultivation, *Better Fruit*, March, 1932.
300. ———, and C. L. Vincent: Red raspberry growing, *Wash. Bull.* 172, 1932.
301. Long, J. H., and A. E. Murneek: Nitrogen and carbohydrate content of the strawberry plant, *Mo. Res. Bull.* 252, 1937.
302. Longley, A. E.: Cytological studies in Rubus, *Am. J. Botany*, **11**:249–282, 1924.
303. ———: Chromosomes and their significance in strawberry classification, *J. Agr. Research*, **32**:559–568, 1926.
304. ———: Chromosomes in Vaccinium, *Science*, **66**:566–568, 1927.
305. ———, and G. M. Darrow: Cytological studies of diploid and polyploid forms of raspberries, *J. Agr. Research*, **26**:737–748, 1924.
306. Loomis, N. H.: Rootstocks for grapes in the South, *Proc. Am. Soc. Hort. Sci.*, **42**:380–382, 1943.
307. ———: Influence of time and method of pruning on yields of muscadine grapes, *Proc. Am. Soc. Hort. Sci.*, **42**:418–420, 1941.
308. Loree, R. E.: Nutrient requirements of the strawberry, *Mich. State Coll. Agr. Tech. Bull.* 70, 1928.
309. ———: Strawberry growing, *Mich. State Coll. Agr. Spec. Bull.* 182, 1928.
310. Lott, R. V.: Correlation of chemical composition with hardiness in brambles, *Mo. Res. Bull.* 95, 1926.
311. ———: An important varietal characteristic of the red raspberry, *Proc. Am. Soc. Hort. Sci.*, **27**:139–141, 1931.
312. ———: Fruiting habit of the red raspberry, *Proc. Am. Soc. Hort. Sci.*, **27**:141, 1931.
313. ———: Raspberry investigations, *Colo. Bull.* 367, 1931.
314. MacDaniels, L. H.: Fruit bud formation in Rubus and Ribes, *Proc. Am. Soc. Hort. Sci.*, **19**:194–200, 1923.
315. Macoun, W. T., and M. B. Davis: The strawberry, *Can. Dep. Agr. Bull.* 80, 1927.

316. Magoon, C. A., and E. Snyder: Grapes for different regions, *U.S. Dept. Agr. Bull.* 1936, 1943.
317. ———, *et al.*: Rootstocks for Concord, Ontario, and Delaware grapes, *Proc. Am. Soc. Hort. Sci.*, **46**:222–226, 1945.
318. Mangelsdorf, A. J.: Origin of the garden strawberry, *J. Hered.*, **18**:177–184, 1927.
319. Maney, T. J.: Grape pruning, *Ia. Bull.* 160, 1915.
320. Mann, C.: Root and shoot growth in the strawberry, *Ann. Botany*, **44**:55–86, 1927.
321. ———, and E. Ball: Root and shoot growth in the strawberry, *J. Pomology Hort. Sci.*, **5**:149–169, 1926.
322. Marshall, R. E.: Fertilizing the black raspberry, *Mich. State Coll. Agr. Quart. Bull.*, **12**:123–128, 1930.
323. ———: Black raspberry studies, *Mich. State Coll. Agr. Tech. Bull.* 111, 1931.
324. ———: Transpiration rates and suction forces of fruiting canes and current season shoots of the black raspberry, *Proc. Am. Soc. Hort. Sci.*, **29**:295–299, 1933.
325. ———: Transpiration rates of fruiting canes and current season shoots of the black raspberry, *Proc. Am. Soc. Hort. Sci.*, **34**:389–394, 1937.
326. McCown, M.: Humus and cultivation govern berry yields, *Hoosier Hort.*, **15**:43–46, 1933.
327. ———, and C. E. Baker: Strawberries, *Purdue Bull.* 351, 1929.
328. McWhorter, O. T.: Training boysenberries and youngberries, *Ore. Ext. Circ.* 356, 1940.
329. ———, and W. F. Cyrus: After harvest care of strawberry plants, *Ore. Ext. Circ.* 328, 1939.
330. Merchant, C. H.: An economic study of 239 blueberry farms in Washington and Hancock counties, *Me. Bull.* 351, 1929.
331. Morris, H. F.: Blackberry and dewberry varieties, *Texas Bull.* 558, 1938.
332. ———: Effects of partial sterility on fruit and cane development of blackberry and dewberry varieties, *Proc. Am. Soc. Hort. Sci.*, **35**:492–494, 1938.
333. Morris, L. S., and J. W. Crist.: Influence of reaction of culture medium on growth of strawberry plants, *Mich. State Coll. Agr. Tech. Bull.* 77, 1927.
334. Morrow, E. B.: Cross-pollination vs. self-pollination in the cultivated blueberry, *Proc. Am. Soc. Hort. Sci.*, **42**:469–472, 1943.
335. ———, and J. H. Beaumont: Effect of age on plant of flower production and yield of strawberries, *Proc. Am. Soc. Hort. Sci.*, **28**:206–210, 1932.
336. ———, and G. M. Darrow: Effect of renovation of beds after harvest on yield and grade of strawberries, *Proc. Am. Soc. Hort. Sci.*, **41**:195–197, 1942.
337. Morse, F. W.: A chemical study of cranberries, *Mass. Bull.* 265, 1930.
338. Mortensen, E.: Strawberry varieties, *Texas Bull.* 556, 1937.
339. Mowry, H., and A. F. Camp: Blueberry culture, *Fla. Bull.* 194, 1928.
340. Munson, T. V.: "Foundations of American Grape Culture," New York, Orange Judd Publishing Co., 1909.

341. Oberle, G. D.: A genetic study of variations in floral morphology and function in cultivated forms of Vitis, *N.Y. Tech. Bull.* 250, 1938.
342. ——: Grafting American grapes on vigorous rootstocks, *N.Y. Exp. Sta., Farm Research*, Oct., 1945.
343. Olmo, H. B.: Pollination of the Almeria grape, *Proc. Am. Soc. Hort. Sci.*, **42**:401–406, 1943.
344. ——: Correlations between seed and berry development in some seeded varieties of V. vinifera, *Proc. Am. Soc. Hort. Sci.*, **48**:291–297, 1946.
345. Overholser, E. L., and L. L. Claypool: Relation of fertilizers to respiration and certain physical properties of strawberries, *Proc. Am. Soc. Hort. Sci.*, **28**:220–224, 1932.
346. Palmer, E. F.: Currants and gooseberries, *Ont. Dep. Agr. Bull.* 318, 1926.
347. ——: Fruit varieties, *Ont. Dep. Agr. Bull.* 430, 1943.
348. ——, and W. J. Strong: A note on raspberry breeding, *Sci. Agr.*, **7**:387, 1927.
349. ——, and J. R. Van Haarlem: The grape, *Ont. Dep. Agr. Bull.* 328, 1927.
350. Park, J. W.: American fruit and vegetable auctions, *U.S. Dep. Agr. Dep. Cir.* 250, 1932.
351. Partridge, N. L.: A note on the fruiting habit of the Concord grape, *Proc. Am. Soc. Hort. Sci.*, **18**:193–196, 1922.
352. ——: Grape production, *Mich State Coll. Agr. Spec. Bull.* 121, 1923.
353. ——: Further observations on the fruiting habit of the Concord grape, *Proc. Am. Soc. Hort. Sci.*, **19**:180–183, 1923.
354. ——: Profitable pruning of the Concord grape, *Mich. State Coll. Agr. Spec. Bull.* 141, 1925 (1929).
355. ——: The fruiting habits and pruning of the Concord grape, *Mich. State Coll. Agr. Bull.* 69, 1925.
356. ——: Growth and yield of Concord grape vines, *Proc. Am. Soc. Hort. Sci.*, **22**:84–87, 1926.
357. ——: The use of the growth-yield relationship in field trials with grapes, *Proc. Am. Soc. Hort. Sci.*, **23**:131–134, 1927.
358. ——: The young vineyard, *Mich. State Coll. Agr. Cir.* 124, 1929.
359. ——: Cultural methods in the bearing vineyard, *Mich. State Coll. Agr. Cir.* 130, 1930.
360. ——: The fruiting habits and pruning of the Campbell Early grape, *Mich. State Coll. Agr. Tech. Bull.* 106, 1930.
361. ——: Relation of blossom formation in the Concord grape to current season conditions, *Proc. Am. Soc. Hort. Sci.*, **26**:261–264, 1930.
362. ——: Moore Early grape not recommended for Michigan, *Mich. State Coll. Agr. Quar. Bull.*, **13**:130–131, 1931.
363. ——: Influence of long pruning and thinning upon the quality of Concord grapes, *Proc. Am. Soc. Hort. Sci.*, **28**:144–146, 1932.
364. ——: Effect of fruit production and fertilizer treatments on the maturity of Concord grapes, *Proc. Am. Soc. Hort. Sci.*, **28**:147–150, 1932.

365. ———, and J. O. Veatch: Fertilizers and soils in relation to Concord grapes, *Mich. State Coll. Agr. Tech. Bull.* 114, 1931.
366. Peacock, N. D.: Strawberry production, *Tenn. Spec. Circ.* 231, 1945.
367. Perold, A. I.: "A Treatise on Viticulture," New York, The Macmillan Co., 1927.
368. Pickett, W. F.: A preliminary study of the fruiting habit of the Worden grape, *Proc. Am. Soc. Hort. Sci.*, **23**:135–138, 1927.
369. ———: Further studies on the fruiting habit of the grape, *Proc. Am. Soc. Hort. Sci.*, **24**:151–154, 1928.
370. ———: Further studies on the fruiting habit of the Worden grape, *Proc. Am. Soc. Hort. Sci.*, **26**:269–271, 1930.
371. Plackidas, A. G.: The rosette disease of blackberries and dewberries, *J. Agr. Research*, **54**:275–303, 1937.
372. Price, J. C. C.: Grape varieties, *Miss. Bull.* 281, 1930.
373. Reimer, F. C., and L. R. Detjen: Self-sterility of the Scuppernong and other muscadine grapes, *N.C. Bull.* 209, 1910.
374. Reynolds, H., and J. E. Vaile: Effects of rootstock upon composition and quality of fruit of Concord, Campbell Early, and Moore Early grapes, *Ark. Bull.* 421, 1942.
375. Richey, H. W., and J. C. Schiletter: The time of flower bud formation in the Dunlap strawberry, *Proc. Am. Soc. Hort. Sci.*, **25**:192–194, 1928.
376. ———, and ———: Runner plant formation in the Dunlap strawberry, *Proc. Am. Soc. Hort. Sci.*, **26**:281–285, 1930.
377. ———, and C. E. Asbury: Carbohydrate composition of Dunlap strawberry plants, *Proc. Am. Soc. Hort. Sci.*, **27**:179–183, 1931.
378. ———, and H. A. Bowers: Correlation of root and top growth of the Concord grape and translocation of elaborated plant food during the dormant season, *Proc. Am. Soc. Hort. Sci.*, **21**:33–39, 1925.
379. Roberts, O. C., and A. S. Colby: Identification of certain red and purple raspberry varieties by means of primocanes, *Proc. Am. Soc. Hort. Sci.*, **42**:457–462, 1943.
380. Roberts, R. H., and E. Struckmeyer: Growth and fruiting of the cranberry, *Proc. Am. Soc. Hort. Sci.*, **40**:373–379, 1942.
381. Rogers, W. S.: Strawberry cultivation, *Ann. Rpt. East Malling Research Sta.*, **16**:52–64, 1930.
382. Ross, H., and E. C. Auchter: A production and economic study of the black raspberry industry, *Md. Bull.* 322, 1930.
383. Ruef, J. V., and H. W. Richey: Flower bud formation in the Dunlap strawberry, *Proc. Am. Soc. Hort. Sci.*, **22**:252–260, 1926.
384. Runner, G. A.: Controlling grape insects and the present situation regarding arsenical residue, *Proc. Ohio State Hort. Soc.*, **65**:206–211, 1932.
385. Savage, E. F., and G. M. Darrow: Growth response of blueberries under clean cultivation and various kinds of mulch materials, *Proc. Am. Soc. Hort. Sci.*, **40**:338–340, 1942.

386. Schilerter, J. C.: Fruit bud differentiation in the Dunlap strawberry in relation to the age and position of the plant, *Proc. Am. Soc. Hort. Sci.*, **28**:216–219, 1932.
387. ———: Time of bud differentiation in the Dunlap strawberry, *Proc. Am. Soc. Hort. Sci.*, **29**:325–329, 1933.
388. ———, and H. W. Richey: Flower counts of the Dunlap strawberry plant, *Proc. Am. Soc. Hort. Sci.*, **26**:265–268, 1930.
389. ———, and ———: Four year's study on the time of flower bud formation in the Dunlap strawberry, *Proc. Am. Soc. Hort. Sci.*, **27**:175–178, 1931.
390. Schlatter, F. P.: Report on fertilizer experiments with cranberries, *Am. Cran. Grow.*, **48**:9–12, 1917.
391. Schrader, A. L.: The pattern of strawberry root development under the matted and thinned row, *Proc. Am. Soc. Hort. Sci.*, **38**:413–416, 1941.
392. Schuster, C. E.: Field production of Ettersburg 121 strawberry, *Ore. Circ.* 67, 1926.
393. ———, *et al.:* Effect of irrigation on major berry crops, *Ore. Bull.* 277, 1931.
394. Scott, L. E.: An instance of boron deficiency in the grape under field conditions, *Proc. Am. Soc. Hort. Sci.*, **38**:375–378, 1941.
395. Scoville, G. P.: Cost of grape training systems, *Cornell Agr. Econ. Bull.* 75, 1932.
396. ———, *et al.:* Grape varieties, yields, production costs, and cost of maintaining vines and trellis, *U.S. Dep. Agr. Econ. Mimeo. Rpt.*, 1932.
397. Shear, C. L., *et al.:* Fungous diseases of the cultivated cranberry, *U.S. Dep. Agr. Tech. Bull.* 258, 1931.
398. Shear, S. W., and H. F. Gould: Economic status of the grape industry, *Calif. Bull.* 429, 1927.
399. Shaulis, N.: Heavy pruning and Fredonia yields, *Farm Res.* (Geneva, N. Y.), Jan., 1, 1947.
400. Shepard, P. H.: Grafted grapes, *Mo. Bull.* 30, 1941.
401. ———: Concord, Moore and Campbell grown on vigorous rootstocks, *Mo. Fruit Sta. Bull.* 32, 1946.
402. Shoemaker, J. S.: Fruit varieties, *Ohio Bull.* 407, 1927.
403. ———: Raspberry improvement studies, *Proc. Am. Soc. Hort. Sci.*, **24**:149–151, 1928.
404. ———: Pruning the raspberry and blackberry, *Ohio Bimo. Bull.*, May–June, 1928.
405. ———: Runner formation in the Howard 17 strawberry, *Ohio Ann. Rpt.*, **47**:86–87, 1929.
406. ———: The strawberry, *Ohio Bull.* 444, 1929.
407. ———: Studies with Premier strawberry, *Ohio Ann. Rpt.*, **48**:105–106, 1930.
408. ———: Tip layering the black raspberry, *Ohio Spec. Circ.*, **30**:18–19, 1930.
409. ———: Fertilizer studies with the strawberry, *Ohio Spec. Circ.*, **30**:17–18, 1930.
410. ———: Pruning studies with the Cumberland black raspberry, *Ohio Bimo. Bull.*, Sept.–Oct., 1930.

411. ———: Propagation studies with the black raspberry, *Proc. Am. Soc. Hort. Sci.*, **27**:142–145, 1931.
412. ———: Howard 17 (Premier) as a pollenizer for Sample, *Ohio Ann. Rpt.*, **49**:112, 1931.
413. ———: Three promising new varieties of small fruits, *Ohio Bimo. Bull.*, March–April, 1931.
414. ———: Effect of fertilizers on the yield of currants, *Ohio Ann. Rpt.*, **50**:101, 1932.
415. ———: Costs of development and production per acre of black raspberries, *Ohio Ann. Rpt.*, **50**:102, 1932.
416. ———: Raspberry studies, *Ohio Spec. Cir.* 41, 1932.
417. ———: Strawberry studies, *Ohio Spec. Cir.* 41, 1932.
418. ———: The use of nitrogen fertilizer on red raspberries, *Ohio Bimo. Bull.*, **19**:97–103, 1934.
419. ———: Sugar, acidity, and juice color determinations in grapes, *Ohio Bull.* 550, 1935.
420. ———: Effect of fertilizer and mulch on yield of red currants, *Ohio Bimo. Bull.*, **20**:82–83, 1935.
421. ———: Horticulture, *Can. Legion War Services*, 1943.
422. ———: "Vegetable Growing," New York, John Wiley & Sons, Inc., 1947.
423. ———, *et al.*: Raspberries and blackberries, *Ohio Bull.* 454, 1930.
424. ———, and E. W. Grave: Relation of nitrogen fertilizer to the firmness and composition of strawberries, *Ohio Bull.* 466, 1930.
425. Shrader, A. L.: Pruning and fruiting studies of the Concord grape, *Proc. Am. Soc. Hort. Sci.*, **25**:217–219, 1929.
426. ———: Growth studies of the Concord grape, *Proc. Am. Soc. Hort. Sci.*, **19**:116–122, 1923.
427. ———: Seasonal changes in the chemical composition of the Concord grape vine, *Proc. Am. Soc. Hort. Sci.*, **21**:39–44, 1925.
428. ———: The Concord grape—pruning and chemical studies in relation to the fruiting habit of the vine, *Md. Bull.* 286, 1926.
429. ———: Effect of fruiting on the shoot growth of the Concord grape, *Proc. Am. Soc. Hort. Sci.*, **28**:137–142, 1932.
430. ———: Further studies on the effect of fruiting on the shoot growth of the Concord grape, *Proc. Am. Soc. Hort. Sci.*, **28**:137–142, 1932.
431. ———: Effect of the relative vigor of the vine at planting on the fruiting and growth of the Concord grape, *Proc. Am. Soc. Hort. Sci.*, **29**:290, 1933.
432. ———: Effect of defoliation on the fruiting of Concord grape shoots, *Proc. Am. Soc. Hort. Sci.*, **29**:317, 1933.
433. Shriver, R. L., and R. J. Anderson: Chemical studies of grape pigments, *N.Y. Tech. Bull.* 152, 1929.
434. Slate, G. L.: The best parents in strawberry breeding, *Proc. Am. Soc. Hort. Sci.* **28**:107–111, 1932.
435. ———: Red currants and gooseberries, *N.Y. Circ.* 112, 1933.

436. ———: Breeding autumn fruiting raspberries, *Proc. Am. Soc. Hort. Sci.*, **37**:574–578, 1940.
437. ———, and R. C. Collison: The blueberry, *N.Y. Circ.* 189, 1940.
438. ———, *et al.*: Raspberry growing, *N.Y. Circ.* 153, 1945.
439. ———, and W. H. Rankin: Raspberry growing, *N.Y. Bull.* 625, 1933.
440. Smith, W. W.: Improved blueberries, *N.H. Ext. Circ.* 215, 1938.
441. ———, *et al.*: Response of the lowbush blueberry to fertilizer, *Proc. Am. Soc. Hort. Sci.*, **48**:263–268, 1946.
442. Snyder, E.: Susceptibility of grape rootstocks to root knot nematode, *U.S. Dep. Agr. Dep. Circ.* 405, 1936.
443. ———, and F. N. Harmon: The bud-graft method of propagating vinifera grape varieties on rootstocks, *U.S. Dep. Agr. Leaf.* 173, 1939.
444. ———, and ———: Effects of zinc sulfate on Alexandria grape, *Proc. Am. Soc. Hort. Sci.*, **40**:325–327, 1942.
445. Snyder, J. C.: Flower bud formation in the Concord grape, *Botany Gaz.*, **94**:771–779, 1933.
446. ———: Flower bud formation in the Latham raspberry, *Proc. Am. Soc. Hort. Sci.*, **33**:41–42, 1936.
447. ———: Strawberry growing, *Wash. Ext. Bull.* 246, 1938.
448. ———: Growing grapes, *Wash. Ext. Bull.* 271, 1941.
449. ———, and H. W. Richey: Carbohydrate composition of protected and unprotected raspberry canes, *Proc. Am. Soc. Hort. Sci.*, **27**:146–150, 1931.
450. Stene, A. E.: Fertilization of red raspberries, *R.I. Bull.* 229, 1931.
451. ———: Fertilizer treatments of red raspberries, *Proc. Am. Soc. Hort. Sci.*, **33**:41–44, 1936.
452. ———: Observations on blueberry nutrition based on greenhouse culture, *Proc. Am. Soc. Hort. Sci.*, **37**:620–622, 1940.
453. Steuk, W. K.: French-American hybrid grapes, *Ohio Bimo. Bull.*, **31**:186–187, 1946.
454. Stevens, A. E.: Incubator tests to determine the keeping qualities of cranberries, *Wisc. Cranberry Grow.*, **40**:8–12, 1926.
455. Stevens, C. D., *et al.*: The cranberry industry, *Mass. Bull.* 332, 1936.
456. Stout, A. B.: Types of flowers and intersexes with reference to fruit development, *N.Y. Tech. Bull.* 82, 1921.
457. ———: Seedlessness in grapes, *N.Y. Tech. Bull.* 238, 1936.
458. Strong, W. J.: The raspberry and blackberry, *Ont. Dep. Agr. Bull.* 355, 1930 (1942).
459. ———: The strawberry, *Ont. Dep. Agr. Bull.* 335, 1928 (1942).
460. ———: Results with fertilizers on the red raspberry, *Sci. Agr.*, **16**:424–439, 1936.
461. ———: Currants and gooseberries, *Ont. Dep. Agr. Bull.* 332, 1936.
462. Strowbridge, J. W.: Origin and distribution of the commercial strawberry crop, *U.S. Dep. Agr. Tech. Bull.* 180, 1930.
463. Sudds, R. H.: Horticultural investigations, *Pa. Bull.* 230, 1928.

464. ———: Morphological changes and the origin of roots in tip-layered Cumberland raspberry plants, *Proc. Am. Soc. Hort. Sci.*, **32**:401–406, 1935.
465. ———: Origin of roots in several types of red and black raspberry stem cuttings, *Proc. Am. Soc. Hort. Sci.*, **33**:380–385, 1936.
466. ———: Effects of the personal equation in setting on the stand of black raspberry plants, *Proc. Am. Soc. Hort. Sci.*, **33**:415–416, 1936.
467. Swartwout, H. G.: Gooseberries and currants, *Mo. Bull.* 232, 1925.
468. ———: Blackberry, raspberry and dewberry culture, *Mo. Bull.* 231, 1925.
469. ———: Fruiting habit of the grape, *Proc. Am. Soc. Hort. Sci.*, **22**:70–80, 1926.
470. ———: Grape growing, *Mo. Bull.* 208, 1926.
471. Szymoniak, B.: Fertilizer test for strawberries, *La. Rpt.* pp. 52–53, 1925.
472. ———: Blackberry and muscadine grape culture, *La. Bull.* 213, 1930.
473. ———: Strawberry culture in Louisiana, *Proc. Am. Soc. Hort. Sci.*, **28**:173–175, 1932.
474. Talbert, T. J.: Strawberries, *Mo. Bull.* 242, 1926 (1947).
475. Taylor, R. W.: Winter application of fertilizer to strawberries, *Proc. Am. Soc. Hort. Sci.*, **27**:187–189, 1931.
476. ———: Influence of nitrogenous fertilizers applied at different dates on the numbers of flower clusters, flowers, and fruits of the strawberry, *Proc. Am. Soc. Hort. Sci.*, **29**:313–317, 1933.
477. Teske, A. H.: Summer care of the raspberry, *Fruits & Gardens*, July, 1927.
478. ———, and V. R. Gardner: Management methods in the raspberry plantation, *Mich. State Coll. Agr. Spec. Bull.* 165, 1927.
479. Thayer, P.: The red and white currants, *Ohio Bull.* 371, 1923.
480. Thomsen, F. L., and G. B. Thorne: Economics of strawberry production and marketing, *Mo. Bull.* 262, 1928.
481. Tucker, L. R.: Growth habits of the strawberry as affected by fertilizer, *Proc. Am. Soc. Hort. Sci.*, **23**:149–152, 1927.
482. Upshall, W. H.: An important character in strawberry variety classification, *Sci. Agr.*, **8**:793–794, 1928.
483. Vaile, J. E.: Influence of rootstocks on the yield and vigor of American grapes, *Proc. Am. Soc. Hort. Sci.*, **35**:471–474, 1937.
484. ———: Grape varieties, *Ark. Bull.* 379, 1939.
485. Van Haarlem, J. R., and W. H. Upshall: Pruning and fertilizing experiments with Concord grapes, *Sci. Agr.*, **18**:485–499, 1938.
486. Valleau, W. D.: Sterility in the strawberry, *J. Agr. Research*, **12**:613–669, 1918.
487. Vandenburg, J. T., and G. P. Scoville: Growing and marketing grapes, *Pa. Bull.* 260, 1930.
488. Vercier, J.: Influence of soil and fertilizer on yield, chemical composition, size and edible quality of strawberries, *J. Soc. Nat. Hort.* (France) **15**:549, 1914.
489. Verner, L.: Growing strawberries, *Idaho Bull.* 249, 1942.
490. Viljoen, J. A., and E. B. Fred: Effect of different kinds of wood and of wood pulp cellulose on plant growth, *Soil Sci.*, **17**:199–208, 1924.

491. Vincent, C. L., and L. L. Claypool: Strawberry growing, *Wash. Bull.* 171, 1932.
492. Wakabayashi, S.: Injurious effect of submergence on the cranberry plant, *N.J. Bull.* 420, 1925.
493. Waldo, G. F.: Fruit-bud development in strawberry varieties and species, *J. Agr. Research*, **40**:393–407, 1930.
494. ———: Fruit-bud formation in everbearing strawberries, *J. Agr. Research*, **40**:409–416, 1930.
495. ———: Effects of irrigation and of plant spacing upon runner production and fruit yield of the Corvallis strawberry, *Proc. Am. Soc. Hort. Sci.*, **44**:289–294, 1944.
496. ———, and G. M. Darrow: Hybrids of the Hautbois strawberry, *J. Hered.*, **19**:509–510, 1928.
497. ———, and G. M. Darrow: Breeding autumn-fruiting raspberries, *Proc. Am. Soc. Hort. Sci.*, **39**:274–278, 1941.
497a. ———, and H. Hartman: Culture of trailing berries, *Ore. Bull.* 441, 1946.
498. ———, and O. T. McWhorter: Crown division a means of propagating everbearing strawberries, *Ore. Bull.* 416, 1943.
499. ———, *et al.*: New berries, *Ore. Bull.* 416, 1943.
500. Wallace, T.: Effects of manurial treatments on the chemical composition of gooseberry bushes, *J. Pomology Hort. Sci.*, **7**:130–145, 1928.
501. ———: The nutrition and manuring of soft fruits, *Imp. Bur. Fruit Prod.*, 6, 1936.
502. Waltman, C. S.: Effect of hydrogen-ion concentration on the growth of strawberries, *Ky. Bull.* 321, 1931.
503. Wander, I. W., and J. H. Gourley: Increasing available potassium to greater depths in an orchard soil by adding potash fertilizer on a mulch, *Proc. Am. Soc. Hort. Sci.*, **46**:21–24, 1945.
504. ———: Physical and chemical studies of soils, *Ohio Bull.* 663, 1946.
505. Ware, L. M.: Propagation studies with the southern blueberry, *Miss. Bull.* 280, 1930.
506. Weaver, J. E., and W. E. Bruner: "Root development of Vegetable Crops," New York, McGraw-Hill Book Co., 1918.
507. Wellington, R.: Summer pruning vs. non-summer pruning of grapes, *N.Y. Hort. Soc.*, pp. 204–207, 1929.
508. ———: The value of the European grape in breeding grapes for New York State, *Proc. 6th Intern. Genetic. Congr.*, **2**:208–209, 1932.
509. White, P. R.: Physiological anatomy of the strawberry, *J. Agr. Research*, **35**:481–492, 1927.
510. White, E. W.: Loganberry culture, *B.C. Circ.* 54, 1938.
511. ———: Strawberry culture, *B.C. Circ.* 58, 1940.
512. Whitehouse, W. E.: Nutritional studies with the strawberry, *Proc. Am. Soc. Hort. Sci.*, **25**:201–206, 1929.

513. ———— *et al.*: Production and marketing of strawberries, *Md. Bull.* 515, 1939.
514. Wiegand, E.: The "frozen-pack" method of preserving berries, *Ore. Bull.* 278, 1931.
515. Wiggans, G. C.: Cane vs. spur pruning for grapes, *Neb. Bull.* 237, 1929.
516. Wiggans, C. B.: Relative value of fruiting shoots arising from primary and secondary buds of Concord grape, *Proc. Am. Soc. Hort. Sci.*, **23**:293–296, 1927.
517. ————: Horticultural investigations, *Ark. Bull.* 231, 1928.
518. Williams, C. F.: Dixie red raspberry, *N.C. Ext. Circ.* 227, 1938.
519. Williams, W. O.: California vineyard experimentation, *Proc. Am. Soc. Hort. Sci.*, **48**:269–278, 1946.
520. Winkler, A. J.: Influence of pruning on the germinability of pollen and the set of berries in Vitis vinifera, *Hilgardia*, **2**:107–124, 1926.
521. ————: Effect of dormant pruning on the carbohydrate metabolism of Vitis vinifera, *Hilgardia*, **4**:153–173, 1929.
522. ————: Berry thinning table grapes, *Blue Anchor*, **7**:18–19, 1930.
523. ————: Relation of number of leaves to size and quality of table grapes, *Proc. Am. Soc. Hort. Sci.*, **27**:158–160, 1931.
524. ————: Pruning vinifera grapevines, *Calif. Circ.* 89, 1934.
525. ———— , and E. M. Shemsettin: Fruit-bud and flower formation in the Sultanina grape, *Hilgardia*, **10**:589–632, 1937.
526. Winter, J. D.: Identification of cultivated raspberries, *Minn. Tech. Bull.* 106, 1931.
527. ————: Market outlets for Minnesota fruits, *Minn. Bull.* 332, 1937.
528. ———— , *et al.*: Packing Minnesota fruits for market, *Minn. Spec. Bull.* 184, 1937.
529. Woods, J. J.: Raspberry growing in British Columbia, *Dom. Dep. Agr. Misc.*, 1937.
530. Woodruff, J. G.: Effects of preservation by freezing on quality of fruits and vegetables, *Proc. Am. Soc. Hort. Sci.*, **28**:507–508, 1932.
531. Wright, K. T., and S. Johnston: Small fruit costs, *Mich. Circ.* 203, 1946.
532. Yarnell, S. H.: Chromosome behavior as a factor in berry breeding, *Proc. Am. Soc. Hort. Sci.*, **28**:114–117, 1932.
533. Yeager, A. F., and E. Latzke: Gooseberries, *N.D. Bull.* 267, 1933.
534. Young, H. C., and J. S. Shoemaker: Healthy black raspberry plants, *Ore. Bimo. Bull.* Jan.–Feb., 1930.
535. Zellar, S. M.: Crinkle disease of the strawberry, *Ore. Bull.* 319, 1933.
536. ———— : Verticillium wilt of cane fruits, *Ore. Bull.* 344, 1936.

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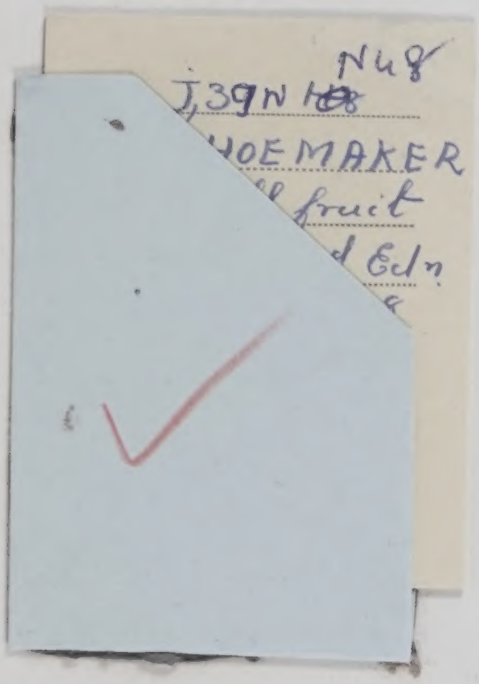
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